INTO ELECTRONICS

A WIA (NSW) EDUCATION SERVICE PUBLICATION

INTO ELECTRONICS

AN INTRODUCTORY TEXT

by

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PREFACE

INTRODUCTION

This is to introduce the first edition of "INTO ELECTRONICS". The book is for those of all ages who are newcomers to electronics and radio.

The book aims to provide basic information about fundamental theory and basic electronic components. To aid learning simple experiments (marked with an 'E'), some projects and sets of revision questions are included.

The text covers the content of the new Elementary Stage syllabus 1980 as produced by the W.I.A. (N.S.W. Div.) Education Service. For students of clubs affiliated with the Education Service an externally set and marked test is available. From this exam successful students are entitled to an Elementary Certificate. For information about this service write to the W.I.A. (N.S.W. Div).

The content of this book is relevant for the Theory Section of the Novice Amateur Operators Certificate of Proficiency examination (Novice Amateur Licence). This book is the first in a series of texts for students studying to obtain their Novice Amateur Licence.

It is noted that much of the material in this text is based on the book "Elementary 1 Electronics Notes" by D. Wilson. This text now replaces that set of notes.

ACKNOWLEDGMENTS

Artwork for circuits and diagrams was produced by Dave Wilson VK2ZCA, cartoons were drawn by Ken Hargreaves VK2AKH while photographs were taken by Dave Wilson and Derek Lark VK2DOA. The final text arrangement was produced by Dave Wilson and Ian Hook.

Cells and batteries for photography were supplied by Eveready while Dick Smith Electronics supplied some artwork.

Assistance in proof reading was given by Arthur Hart VK2BXN, Cress Clarke VK2AYB, Elisabeth Dark and Wendy Wilson.

ELECTRONICS AROUND US

In this day and age we are surrounded by electronic devices. These devices form an important part of our life style.

We communicate by telephone and two way radio systems. Radio, TV and Hi Fi sound systems entertain us. Calculators and computers allow difficult calculations to be performed in seconds.

There is no doubt that most electronic devices are complex. A glance inside a transistor radio seems to show a bewildering maze of wire leads and strange components. Yet these devices can be made easier to understand if we can see and understand the electric circuits that are present.

ELECTRIC CIRCUITS

What is an electric circuit? A very simple circuit can be made using a torch cell, a torch bulb and some wire.

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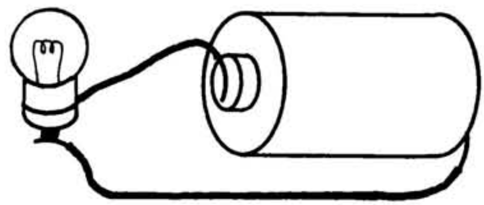


This experiment requires a 1.5 volt "D" size cell and a small torch globe. The wire can be any size as long as it has bare shiny ends.

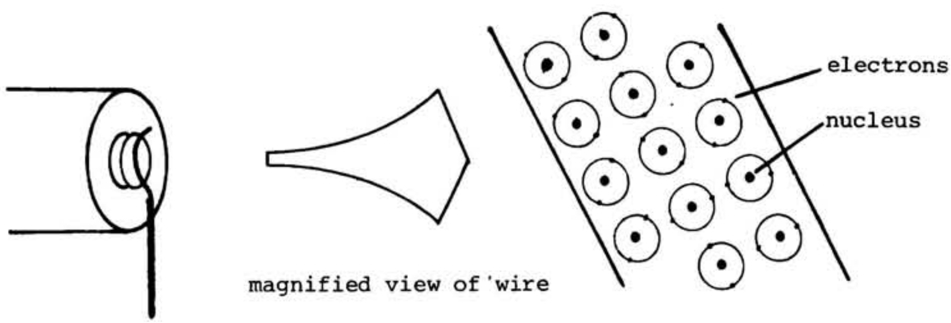
If you build this simple circuit you will find the bulb will glow only when bare wires are touching the cell terminals and the base and sides of the bulb.

Clearly something must be going from the cell terminal to the wire, and the wire to the bulb, and so on. This something is called "ELECTRICITY" and it travels around the loop made by the cell terminal - wire - bulb - wire - other cell terminal. This loop that the electricity flows around is called an ELECTRIC CIRCUIT.

WHAT IS ELECTRICITY?

Electricity flows around circuits - but what exactly is electricity and why does it flow?

To answer these questions it is necessary to know something about the inside structure of the wire.



The diagram shows that the wire is actually made of small particles called atoms. The atoms have a small solid part in the centre called a nucleus. Much smaller particles called electrons circle or orbit around the nucleus.

In a single pure substance such as copper or iron, all the atoms are the same with similar nuclei and electrons in each atom. Different substances will each have their own particular type of atom or groups of atoms. In all atoms, however, the electrons are similar and electrons may transfer from one atom to another.

In a normal atom there must be some force which tends to hold the electrons in orbit around the nucleus. To explain this force some basic ideas about "static" or "stopped" electricity need to be learned.

ABOUT STATIC ELECTRICITY

There are many different examples of static electricity at work.

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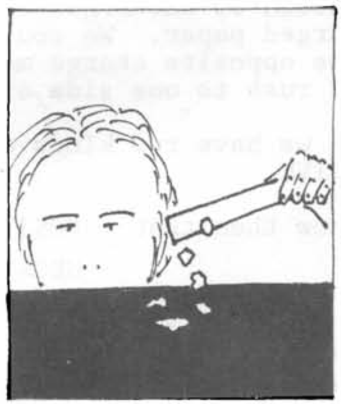
Combing dry hair charges the hair. The static electricity makes the hair stand up.



Rub a plastic ruler on a dry cloth. The ruler becomes charged with static electricity and can attract small pieces of paper.

We can investigate the different effects of static electricity by charging an object. Try hanging two similar blown-up balloons, each by about a metre of cotton, so that they are about 10 cm apart.

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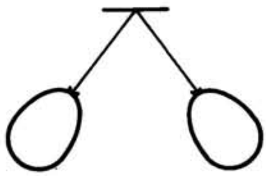


Rub both balloons with something woollen, such as a sweater. Both balloons have the same charge, and they are forced apart

LIKE CHARGES REPEL

Now rub one of the balloons with the wool again but this time look to see what the balloon and the wool do. Since electrons passed between the balloon and the wool they have different charges and tend to come together.

OPPOSITE CHARGES ATTRACT

You will most certainly have noticed that the charged balloons were attracted to uncharged objects too, just as the ruler attracted uncharged paper. We could explain this by saying that perhaps some of the opposite charge moved, in the same way as a crowd of people could rush to one side of a ferry to see something.

Since we have two kinds of charge, we call them POSITIVE and NEGATIVE.

We know then that : POSITIVE AND NEGATIVE CHARGES WOULD <u>ATTRACT</u>.
NEGATIVE AND NEGATIVE CHARGES WOULD <u>REPEL</u>.

This gives us a clue as to what goes on in an atom. The electrons are attracted to the nucleus - clearly <u>THEY</u> must have opposite charges. We say the electrons are charged negatively and the nucleus is charged positively. Since the electrons are all charged negatively it explains why they tend to be spaced evenly through the substance.

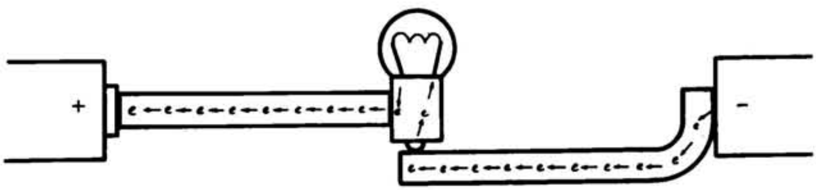
It is important to realise that in substances that have not been charged, the total negative charge from the electrons balances out the total positive charge of the nuclei. Thus the nett overall charge is zero.

WHAT HAPPENS TO THE ATOMS WHEN THE ELECTRICITY FLOWS?

The atoms in a metal wire have many electrons. The outer electrons, because they are a "long" way from the nucleus are not attracted very strongly to the nucleus. Usually they are referred to as "free electrons" since they are able to wander freely from one atom to another.

A diagram of a very thin wire (only two atoms wide) showing the mobile "free" electrons.

Now think of the wire as part of an electric circuit. Remember the torch cell has positive and negative terminals.



Now there will be a drift of electrons from the negative terminal via the circuit (wire and bulb) to the positive end. The electrons will drift from nucleus to nucleus. It is important to realise that the drift in the circuit starts at the moment the wire is touched to the cell terminal. The flow of electrons in a circuit is called an electric current.

CONDUCTORS AND INSULATORS

We say the metal wire is a conductor because it conducts a flow of electrons. Really it means the wire has "free" electrons. Most metals such as iron, zinc, and tin are conductors. Silver and copper are very good conductors.

The opposite of a conductor is an insulator since it will not allow electrons to pass. Atoms in insulators have tightly bonded electrons and will not allow a drift of electrons. Non-metallic substances such as sulphur, oxygen, rubber and most plastics are good insulators.

It is easy to test for insulators and conductors.

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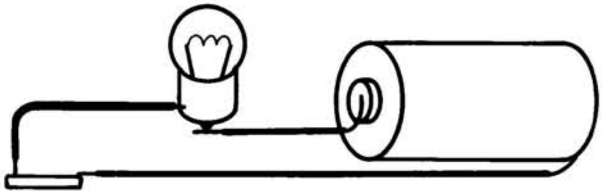


If the substance is a conductor it will allow electrons to flow around the circuit so the light will glow.

If the substance is an insulator it will not allow electrons to flow around the circuit so the light will not glow.

LIST OF CONDUCTORS AND INSULATORS

The list indicates some common conductors and insulators and gives some examples of the way they are used.

CONDUCTORS		INSULATORS	
Name	Use	Name	Use
Silver	very conductive wire	Glass	stand off insulators
Copper	wire leads	Plastic	coating on wires
Aluminium	capacitor plates	Air	general insulator
Brass	nuts and bolts	Porcelain	aerial "egg" insulators
Carbon	electric cells	Fibreglass	in PC board
Iron	heating elements	Wax	in capacitors

So far then ....

ELECTRICITY FLOWS AROUND CIRCUITS

LIKE CHARGES REPEL

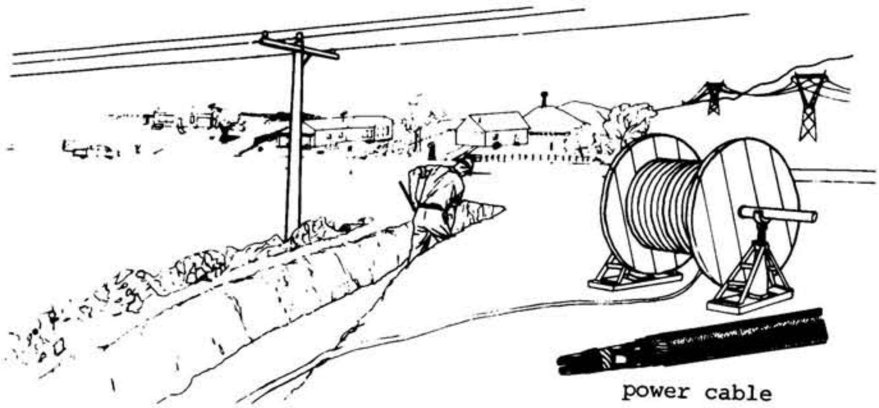
OPPOSITE CHARGES ATTRACT

SUBSTANCES ARE MADE OF ATOMS

ATOMS HAVE A POSITIVE NUCLEUS AND NEGATIVE ELECTRONS

CONDUCTORS HAVE ATOMS WITH FREE ELECTRONS

ELECTRIC CELLS CAUSE ELECTRONS IN A CIRCUIT TO MOVE

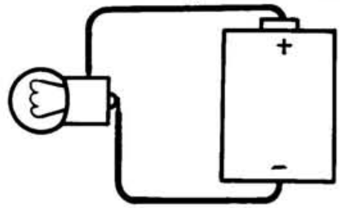


REVISION QUESTIONS

1. *What is an electric circuit?*
2. *What flows around an electric circuit?*
3. *Do positive and negative charges attract or repel?*
4. *What is the rule about positive and negative charges?*
5. *Are electrons charged positive or negative?*
6. *What is the difference between conductors and insulators?*
7. *From the diagram showing the installation of an electric power cable name two conductors and two insulators?*
8. *Name at least two parts of an atom.*
9. *What is special about the electrons of atoms of conductive substances such as metals?*
10. *How would you test to see if a substance was a conductor of electricity.*

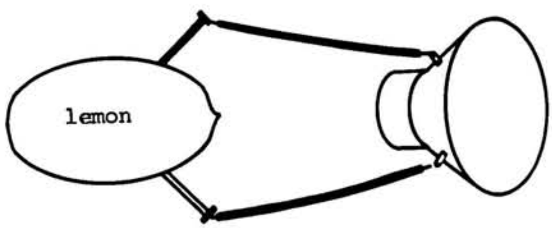
HOW DO CELLS WORK

All cells are like electron pumps.



The cell "pumps" electrons around the circuit by keeping one terminal positive (to attract electrons in the circuit) and keeping the other terminal negative (to supply electrons to the circuit).

E A simple cell can be made using lemon juice as the electrolyte with different metals as the two electrodes.

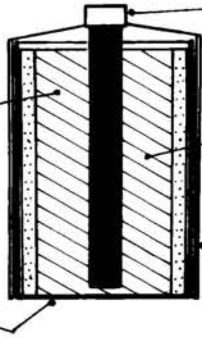


HOW DOES A TORCH CELL WORK?

A torch cell is a primary cell. When new, the cell has special chemicals which keep the terminals of the cell positive and negative. When the chemical has been used the terminals will not stay positive and negative when the cell is pumping, so we say the battery is flat.

INSIDE A TORCH CELL

E An old torch cell can be cut in half using a hacksaw. Wipe the cut cell clean and you will see the zinc and carbon electrode. The black colour is the manganese dioxide depolariser in the electrolyte. Remember to clean the hacksaw when you have finished.



The diagram shows the structure of a typical torch cell. The electrolyte (ammonium chloride) is in the form a semi liquid paste. This type of cell is known as a Leclanche Cell.

The photograph shows a variety of single cells.

They all have a structure similar to the diagram above.

They are all rated as 1½ volt cells. They all would operate a 1½ volt torch bulb to full brightness.

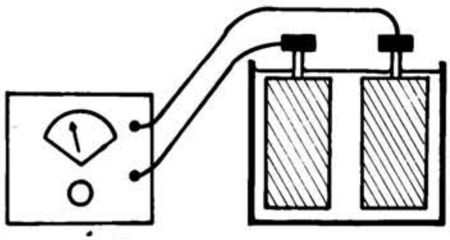
This raises two questions. Why have different sized cells if they all generate the same voltage? <u>and</u> What does voltage mean?

The answer to the first question is that the large cells have more chemicals present and so will supply electricity (in general) for a longer time. We say the bigger cells have a larger electrical capacity.

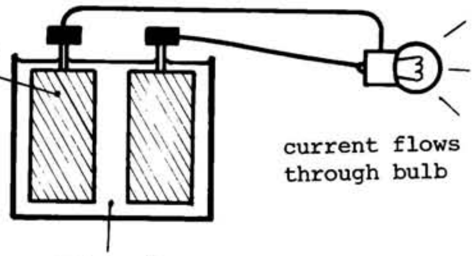
The question about voltage is harder to answer. The voltage tells of the electrical pressure of the cell - the pressure with which the cell "pumps electrons". Often voltage is referred to as the <u>electro-motive force</u> (emf) or potential difference (PD).

SECONDARY OR RECHARGEABLE CELLS

These cells can be recharged with electricity. A good example of a secondary cell is the lead acid cell. This cell has lead electrodes and dilute sulphuric acid electrolyte. The PD of a charged lead acid cell is 2.0 volts.



As electricity flows into cell, the energy is "stored" in chemicals formed on the lead electrodes.



Now the chemicals on the plates are causing electrons to flow in the circuit.

Lead acid cells are charged by connecting them to a source of electricity. This is usually supplied by a mains operated "battery charger". As the cell charges new chemicals form on the lead electrodes and the amount of sulphuric acid in the electrolyte increases. It is the new chemicals which form that contain the stored energy. These chemicals later on can change and the cell can supply electricity.

The increase in sulphuric acid in the electrolyte as the cell is charging causes the electrolyte density or specific gravity to increase. So measurements of the specific gravity of the electrolyte can tell how fully the cell is charged.

We check the specific gravity using the principle that a more dense liquid will cause light objects to float higher. A device to do this is called a hydrometer.

float is low
specific gravity is low
low sulphuric acid content

Battery is DISCHARGED

float is high
specific gravity is high
high sulphuric acid content

Battery is CHARGED

It is important to realise that battery charging also liberates hydrogen gas from the electrolyte. Since this gas is explosive flames should not be brought near the charging battery. Remember too that the electrolyte, sulphuric acid, is both corrosive and poisonous.

NICAD CELLS

Another secondary cell frequently used in portable equipment is the Nicad cell. As the name implies the two electrodes are nickel and cadmium while the electrolyte is potassium hydroxide. These cells usually have a terminal voltage of 1.25 volts.

Nicad cells can be stored for many years and with a few charge/discharge cycles can be brought back to near new condition.

Nicad cells generally need compensating chargers - ones that adjust the charge rate to the condition of the cell.

A summary about cells

ELECTRIC CELLS ACT AS ELECTRON PUMPS
PRIMARY CELLS ARE NOT INTENDED TO BE RECHARGED
SECONDARY CELLS CAN BE RECHARGED WITH ELECTRICITY
VOLTAGE INDICATES ELECTRICAL PRESSURE
DIFFERENT TYPES OF CELLS EACH HAVE A PARTICULAR VOLTAGE

The photo shows some Nicad cells and a simple charging unit.

A six volt lead acid battery - note the three cells wired in series.

The development of minature electronic circuits such as light meters in cameras and amplifiers in hearing aids have produced the need for tiny electric cells.

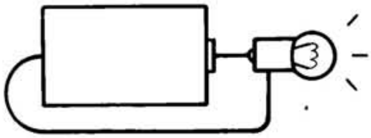
REVISION QUESTIONS

1. *How is an electric cell like an electric pump?*
2. *Draw a cross section of a torch cell - label four parts.*
3. *What is the difference between primary and secondary cells?*
4. *How does a hydrometer work?*
5. *How does the specific gravity of the electrolyte in a lead-acid cell indicate the likely state of charge of the cell?*
6. *What does voltage mean?*
7. *If single torch cells are rated at 1.5 volts, how are large cells different (electrically) from small cells?*
8. *What does PD mean?*
9. *What is the PD of a single (a) lead-acid cell (b) Nicad cell?*
10. *What is the advantage of a torch powered by Nicad cells compared to one powered by the Leclanche type torch cell?*

CELLS AND BATTERIES

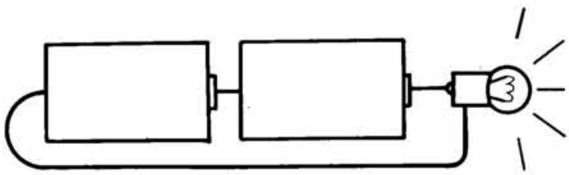
Examine two circuits with different voltages

A. A One Cell Pump $\quad$ 1½ volt "pressure"



BULB IS DIM	this means	ELECTRIC CURRENT IS SMALL	this means	ELECTRICAL PRESSURE IS SMALL

B. A Two Cell Pump $\quad$ 3 volt "pressure"



BULB IS BRIGHT	this means	ELECTRIC CURRENT IS LARGE	this means	ELECTRICAL PRESSURE IS LARGE

These circuits show that:

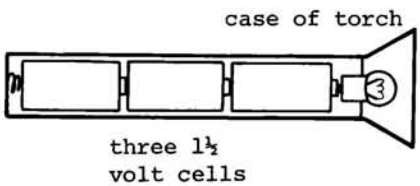
** higher voltage in a circuit causes greater current flow

** higher voltage can be generated arranging cells head to tail.

An arrangement of cells together is called a battery. When the cells are arranged head to tail a SERIES battery is formed.

Total voltage of series battery = Voltage of individual cells X Number of cells in the battery.

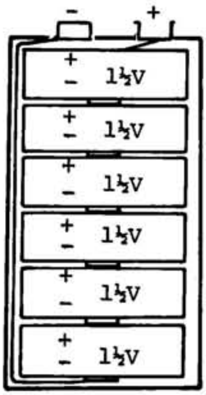
Sometimes the battery is "built" in the appliance.

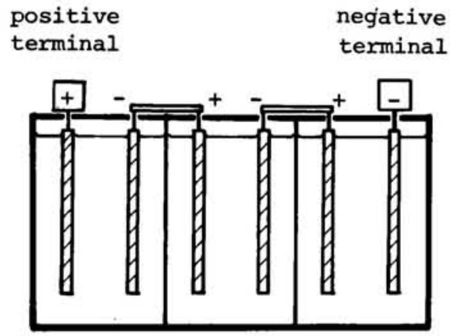


three 1½ volt cells in series.
total voltage = 3x1½
= 4½ volts

Sometimes the cells are arranged in series inside the battery package.

small
cells
in
series
in
battery
packet





A NINE VOLT TRANSISTOR RADIO BATTERY

six $1\frac{1}{2}$ volt cells in series

Voltage = $6 \times 1\frac{1}{2}$

= 9 volts

A SIX VOLT CAR BATTERY

three 2 volt cells in series

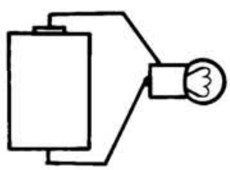
Voltage = 3×2

= 6 volts

The photo shows several series batteries. Each would contain individual cells arranged in series with the positive terminal of one cell connected to the negative terminal of the next. This leaves a positive and a negative terminal of the last and first cell to form the terminals of the battery.

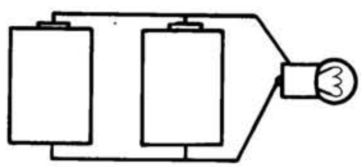
Cells can be arranged in another way.

Battery "A"



Bulb dim so voltage low.

Battery "B"

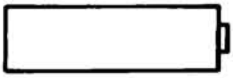


Bulb dim so voltage low.

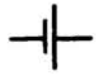
These cells are arranged in parallel. The battery "B" has the same voltage as battery "A". However battery "B" has a larger capacity and so will last longer.

CIRCUITS AND SYMBOLS

Up to this point in the book the circuits have been actually sketched. For simple circuits this is satisfactory but for large circuits <u>standard symbols</u> are used to represent components.

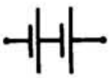


the symbol for a cell is

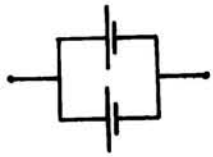


the symbol for a bulb is

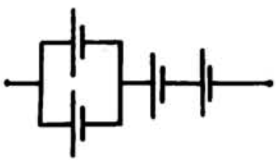
CELLS IN SERIES



CELLS IN PARALLEL



We can use these symbols to show some "series - parallel" arrangements of cells.



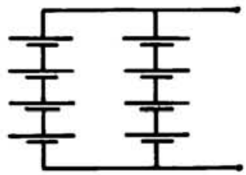
two 1½ volt cells in parallel

= 1½ volts

two 1½ volt cells in series

= 3 volts

in series gives 4½ volts



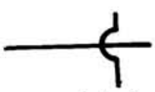
four 1½ volt cells in series gives 6 volts.

two 6 volt "batteries" in parallel give 6 volts

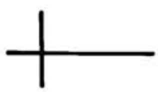
6 volts

SOME OTHER SYMBOLS

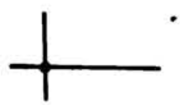
Wires or conductors in circuits are usually shown as firm continuous lines. There are several different ways of showing conductors which cross but do not join and conductors which join.



wires which cross but do not join



usually means wires which do not join

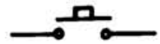


wires which join and connect

Switches are often shown in a circuit. The symbols for some switches are shown.

the symbol for a simple on off switch

the symbol for a normally on switch (normally closed)



the symbol for a push button switch

Switches are used in a circuit to stop or turn on the current flow. When the switch is turned "off" two metal contacts which were touching move apart. In effect a conductor (the metal contacts) have been replaced with an insulator (air). This prevents the flow of current. To turn the switch "on" the metal contacts are made to touch again.

push button switch

toggle switch

micro switch

About batteries we know

> BATTERIES ARE ARRANGEMENTS OF CELLS
>
> SERIES BATTERIES HAVE CELLS WITH THE POSITIVE TERMINAL OF ONE CONNECTED TO THE NEGATIVE TERMINAL OF THE NEXT
>
> SERIES BATTERIES HAVE HIGHER TERMINAL VOLTAGES THAN THE CELLS
>
> PARALLEL BATTERIES HAVE THE SAME VOLTAGE AS THE CELLS

REVISION QUESTIONS

1. What is the difference between a cell and a battery?

Show how you would arrange 1.5 volt cells to form :
(2) a 6 volt battery (3) a 1.5 volt battery.

Show symbols to represent (4) a 1.5 volt cell (5) a 3 volt battery

(6) two 1.5 volt cells in parallel (7) a push button switch

8. How does a switch work?

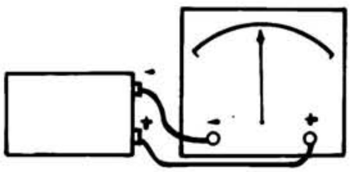
9. Why are cells connected in series?

10. Show a circuit where a 3 volt battery is operating a bulb via a push button switch.

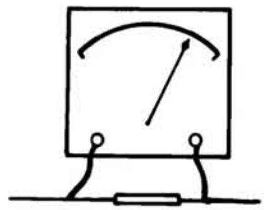
MEASURING WHAT IS HAPPENING IN CIRCUITS

To really know how a circuit is working we need to be able to take measurements of some electrical quantities.

By measuring voltage we know the electrical pressure between two points in a circuit. Voltage is measured using a volt meter. The meter is connected across two points in the circuit. This is termed placing the meter in parallel in the circuit.



To measure voltage of battery, voltmeter is connected in parallel with battery



To measure voltage across resistor, voltmeter is connected in parallel with resistor

Some common voltages are:

Torch cell	1.5 volt
Lead acid cell	2.0 volt
Car battery	12 volt
Output direct from microphone	.01 volt

To make small voltages easier to understand sub units are used.

$\frac{1}{1\ 000}$ volt equals 1 millivolt (mV)

1 volt equals 1 000 millivolts

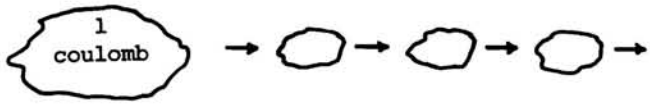
$\frac{1}{1\ 000\ 000}$ volt equals 1 microvolt (μV)

1 volt equals 1 000 000 microvolts

Remember

VOLTS are bigger than MILLIVOLTS are bigger than microvolts

It is important in a circuit to know how much electricity is flowing around a circuit. Current is a measure of electrical flow. The unit of current flow is the ampere. To measure electrical current flow we measure the rate of the moving electrons. Since electrons are small we use "big" units.



A COULOMB OF
ELECTRONS
approximately
.6 200 000 000 000 000 000
electrons

ONE COULOMB OF
ELECTRONS PER
SECOND MEANS A
CURRENT OF ONE
AMPERE

Thus the unit of current flow is the ampere. Some examples of current flow are:

Car headlights	about 4 ampere
Torch bulb	about ¼ ampere

To make small currents easier to understand sub units are used

$\frac{1}{1\ 000}$ ampere equals 1 milliampere (mA)

1 ampere equals 1 000 milliampere

$\frac{1}{1\ 000\ 000}$ ampere equals 1 microampere (1μA)

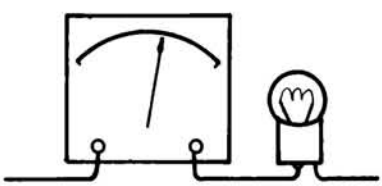
1 ampere equals 1 000 000 microampere

Often ampere are abbreviated to "amps" and milliampere to "milliamps".

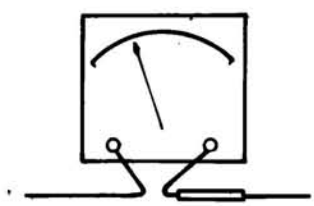
Remember

AMPERE are bigger than MILLIAMPERE are bigger than microampere

Current is measured with ammeters. An ammeter must be wired so the current flows through the circuit and the ammeter. The ammeter is wired in series with the circuit.



The series ammeter measures current flow through the bulb



The ammeter in series with the resistors measures the current flowing

The standard symbols for ammeters and voltmeters are shown.

ammeter

voltmeter

About circuit measurements we know

ELECTRICAL PRESSURE IS MEASURED WITH VOLTMETERS
VOLTMETERS ARE CONNECTED IN PARALLEL IN THE CIRCUIT
ONE COULOMB IS A LARGE QUANTITY OF ELECTRONS
ONE COULOMB PER SECOND MEANS A CURRENT OF ONE AMPERE
ELECTRICAL CURRENT IS MEASURED IN AMPERES
AMMETERS ARE CONNECTED IN SERIES IN THE CIRCUIT

LIFE INSIDE A TORCH CELL

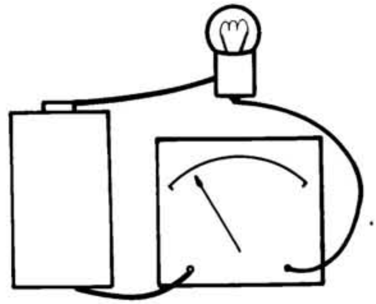
WHEW!!! THAT'S THE THIRD COULOMB
I'VE CARTED IN THE LAST SECOND.

The photo shows a bulb and battery in a simple circuit. The meter on the left is the voltmeter (on the 20 volt scale) and the meter on the right is the ammeter (on the 500 milliampere scale).

REVISION QUESTIONS

1. *Show on a diagram how a voltmeter would be used to measure the voltage of a torch battery.*
2. *What does the voltage between two points in a circuit tell us about the electricity flowing in the circuit?*
3. *How many millivolts equals 2 volts?*
4. *What are the units for electric current?*
5. *Which is the smallest current? 2 microampere, 2 milliampere or 2 ampere?*
6. *Show on a circuit how an ammeter should be wired to measure the current from the battery to a transistor radio.*
7. *Check the photo above. Can you record the voltage and the current? Watch the different scales on the meters.*
8. *Draw the circuit (above) in standard symbols. Check that the voltmeter and ammeter are correctly wired.*
9. *Which type of meter is wired in series in a circuit?*
10. *How many microvolts equal one millivolt?*

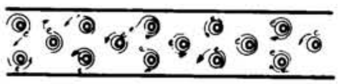
RESISTORS



Why in this circuit does the ammeter indicate a low current when the dry cell has a pressure of 1½ volts and good conductive wires are used?

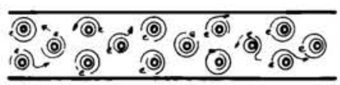
Obviously something must be limiting the flow of current. In this circuit it is the light bulb.

Components which limit the flow of electricity have "resistance" and are called resistors. Electrically, resistors are part way between free flow conductors and no flow insulators.



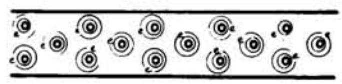
Many "free" electrons. Electricity flows easily.

A CONDUCTOR



Some "free" electrons. Limits the flow of electricity.

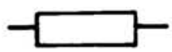
A RESISTOR



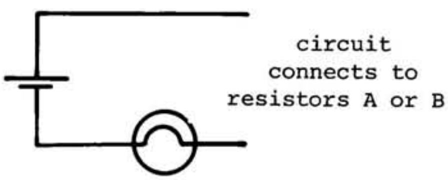
Very few "free" electrons. Prevents flow of electricity.

AN INSULATOR

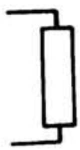
Large currents flowing through resistors make the resistor hot. Some electrical energy is turned to heat. Resistors used in electronics are usually made from carbon or wire. This is usually insulated from accidental contact by an insulated coating.

The standard symbol for a resistor is: 

<u>Checking Two Resistors</u>

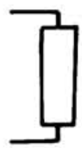


<u>Resistor A</u>



light is dim
Thus current is small

<u>Resistor B</u>



light is bright
Thus current is large

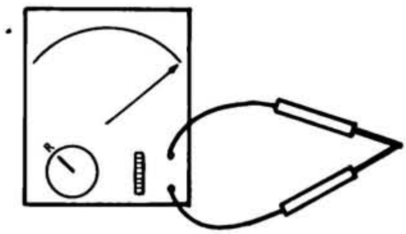
To explain these results we say that:

Resistor A allows a small current therefore a LARGE resistance

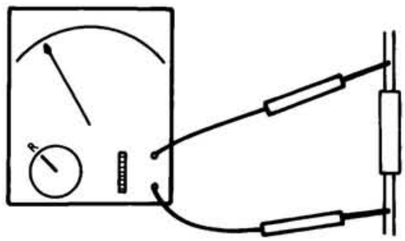
Resistor B allows a LARGE current therefore a small resistance

When a resistor has a low resistance it will allow a large current to flow.

The resistance of a resistor is measured in units called OHMS. Thus to measure the resistance of a resistor we use an Ohm-meter. Ohm-meters work by passing a small current through the resistance being checked.

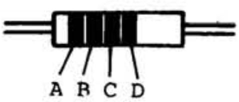


Set dial to resistance.
With leads crossed,
adjust meter to read zero



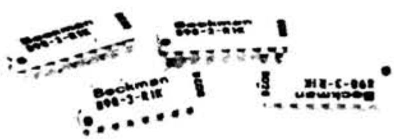
Isolate the resistor
being tested. Then
measure its resistance

Sometimes resistors have their value written on them. Alternatively they may have a series of dots or bands on them of different colours which comply with an International Code. By using a table of the Code the markings allow the value of the resistance to be predicted.



Notice the bands of colour on the resistor.
Band A is close to the end of the resistor.
Bands A, B and C indicate the resistance of the resistor.
Band D is the tolerance band and is closer to the centre of the resistor.

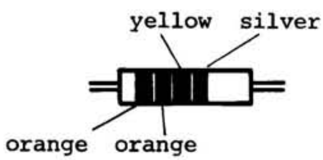
The tolerance band on the resistor tells us how close the actual resistance is to the value indicated by the bands. It is expensive to make resistors precisely on value and in many circuits the resistance can vary by 20% yet the circuit will still function well.



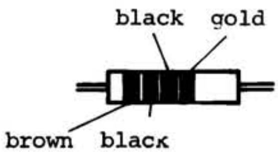
These small packages contain up to 23 identical resistors. They are used in compact circuits.

COLOUR	"A" 1st band or body	"B" 2nd band or body	"C" 3rd band or spot	"D" 4th band extra spot
BLACK	0	0	None	
BROWN	1	1	0	Gold = 5%
RED	2	2	00	
ORANGE	3	3	000	Silver = 10%
YELLOW	4	4	0 000	
GREEN	5	5	00 000	No Colour = 20%
BLUE	6	6	000 000	
VIOLET	7	7	0 000 000	
GREY	8	8	00 000 000	
WHITE	9	9	000 000 000	

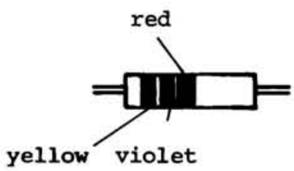
Some Examples:



orange band 1 orange band 2 yellow band 3 silver band 4
3 3 0 000 10%
= 330 000 ohms tolerance 10%



brown band 1 black band 2 black band 3 gold band 4
1 0 5%
= 10 ohms tolerance 5%



yellow band 1 violet band 2 red band 3
4 7 00
= 4 700 ohms tolerance 20%

Since many resistors have very high values it is convenient to use multiplier values.

1 kilohm (k)	equals	1 000	ohms (Ω)
1 Megohm (M)	equals	1 000 000	ohms
1 Megohm	equals	1 000	kilohm

Remember

A MEGOHM is bigger than a KILOHM is bigger than an ohm

Also the multiplier letter (k or M) can be used in place of the decimal point.

Some examples:

330 000 ohms = 330 kilohm = 330 kΩ

4 700 ohms = 4.7 kilohm = 4k7Ω

6 800 000 ohms = 6 800 kilohm
= 6.8 Megohm = 6M8Ω

RESISTORS LIMIT FLOW OF CURRENT

LOW RESISTANCE ALLOWS MORE CURRENT TO FLOW THAN A HIGH RESISTANCE

OHM METERS CAN MEASURE RESISTANCE

RESISTORS ARE MARKED IN A STANDARD COLOUR CODE

REVISION QUESTIONS

1. *What is the symbol for a resistor?*
2. *What function do resistors serve in electrical circuits?*
3. *Which resistor will pass most current in a circuit: a 2 ohm, a 20 ohm or a 2 kilohm?*

What is the resistance of the following resistors? The colours of the bands are given in the correct order.

4. *red - violet - orange - gold*
5. *yellow - white - green - silver*
6. *green - blue - brown*
7. *blue - grey - orange - gold*

List the colours for the bands for these resistors.

8. *1 Megohm 5%*
9. *270 ohms 20%*
10. *910 kilohm 10%*

LOOKING AT RESISTORS

Some points to note:

1. Resistors can come in many different sizes. Large resistors often have resistance wire wound on an insulating former while smaller ones are usually made from moulded carbon compounds.

2. Large resistors can "get rid of" or dissipate heat energy more quickly than small resistors. This means the heat generated in the resistor will be lost without the resistor overheating.

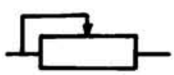
3. Some resistors are variable - they can be mechanically adjusted to give a particular resistance. The resistance element has a constant resistance from one end to the other but the resistance between one end and the moving contact will depend on where along the length of resistance element the moving contact is set.

4. One popular form of variable resistor is called the potentiometer.

A View inside a Potentiometer

The wiper connects the centre terminal to different parts of the resistance track

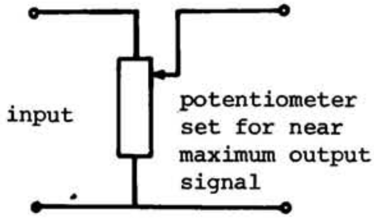
The standard symbols for potentiometers are:

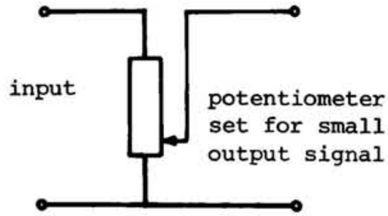


Normal Potentiometer

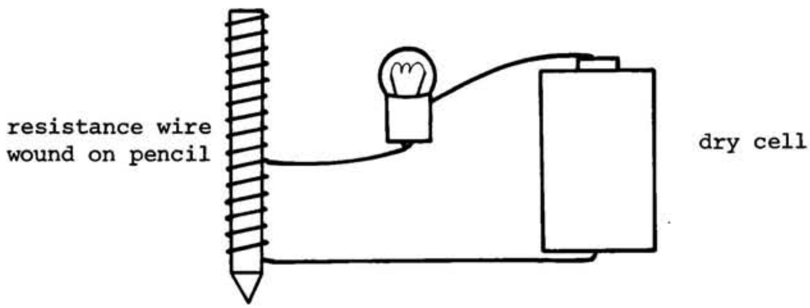
Trim Pot

Potentiometers are particularly useful in amplifiers to control the amount of signal to be passed onto the next stage of the amplifier. They act as volume controls.





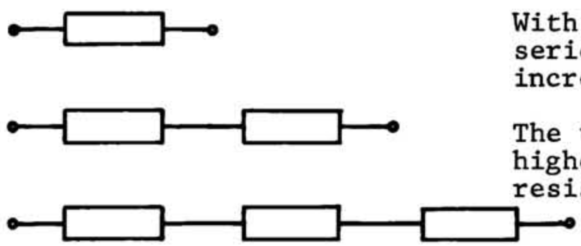
E A simple variable resistance to control the brightness of a light bulb can be made using commercial resistance wire, e.g. Eureka or Nichrome wire, or iron wire, or even a carbon rod from a small cell.



As the moveable wire is touched to different parts of the resistance element different circuit resistances result. This controls the current through the bulb and so changes its brightness.

ARRANGING RESISTORS IN CIRCUITS

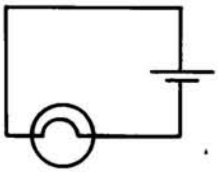
Resistors can be arranged in series - so the current flows through one resistor after another.



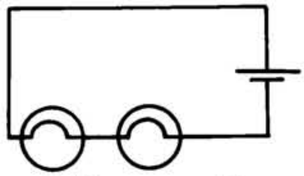
With more resistors in series the total resistance increases.

The total resistance is always higher than the largest resistor present.

E Light bulbs can be used to check this idea about series resistance. Try building these two circuits using torch bulbs and a single torch cell.



Bulb is bright



Bulbs are dim

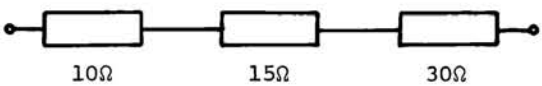
Remember - a torch bulb is a resistor.
- as current decreases bulb becomes dimmer.
- low currents mean MORE resistance.

Did you find putting more resistors in series produced a higher resistance?

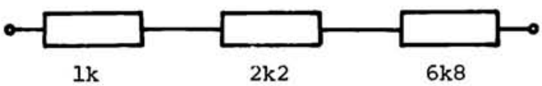
The total resistance of a set of resistors in series is simply the sum of the individual resistances.

Resistance total = Resistance 1 + Resistance 2 + Resistance 3 etc.

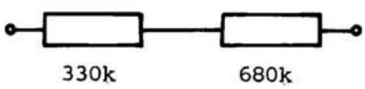
Some examples:



Total resistance is sum of resistances
= 10 + 15 + 30
= 55Ω

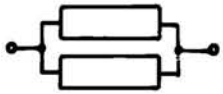


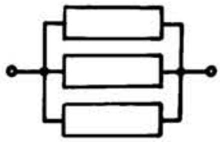
Total resistance is sum of resistances
= 1k + 2k2 + 6k8
= 1.0k + 2.2k + 6.8k
= 9.8k = 9k8



Total resistance is sum of resistances
= 330k + 680k
= 1 010k
= 1 010 000Ω
= 1.01MΩ

When resistors are arranged in parallel the current entering the circuit divides and part flows through each resistance.

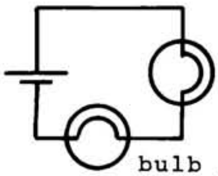


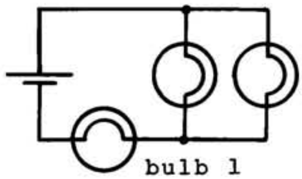


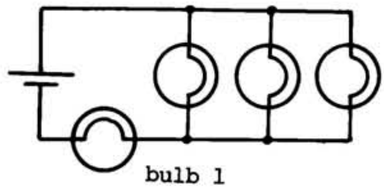
With more resistors in parallel the total resistance becomes less.

The total resistance is always lower than the lowest resistance value present.

E Try this experiment using light bulbs in parallel.







Use Bulb 1 to indicate current.

Remember if Bulb 1 is brighter then current is GREATER.

Also remember that large current means small resistance.

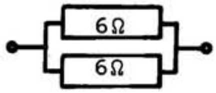
Check the brightness of Bulb 1 with the circuits above. Notice that the circuits have progressively 1, 2 then 3 bulbs in parallel.

Did you find that by putting more bulbs (resistors) in parallel that the total resistance was lowered?

Notice that placing more resistances in parallel produces more conductive paths for the electric current making it easier for the current to pass. This in effect lowers the resistance.

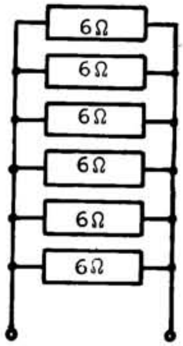
A useful rule about parallel combination of the same resistors is that the total resistance is equal to the resistance of any one resistor divided by the number of resistors.

Examples



$$\text{Total Resistance} = \frac{\text{Resistor value}}{\text{Number of Resistors}}$$

$$= \frac{6}{2} = 3\,\Omega$$



$$\text{Total Resistance} = \frac{\text{Resistor value}}{\text{Number of Resistors}}$$

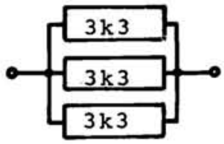
$$= \frac{6}{6} = 1\,\Omega$$

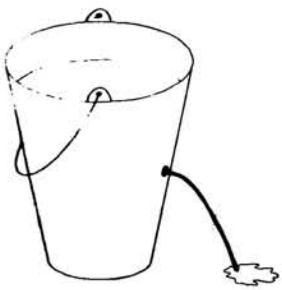
$$\text{Total Resistance} = \frac{\text{Resistor value}}{\text{Number of Resistors}}$$

$$= \frac{3K3}{3} = \frac{3\ 300}{3}$$

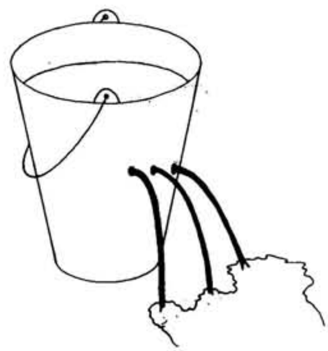
$$= 1\ 100$$

$$= 1K1$$





With a single hole (resistor) the water flow (current) is small.

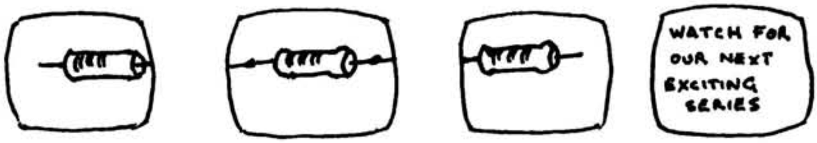


With several holes (like resistors in parallel) the total water flow (current) is large.

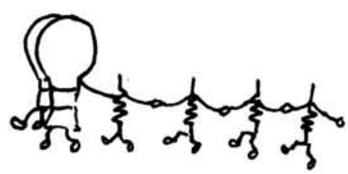
RESISTORS COME IN MANY DIFFERENT FORMS AND SIZES.
LARGE RESISTORS CAN DISSIPATE HEAT ENERGY QUICKLY
POTENTIOMETERS ARE A FORM OF VARIABLE RESISTOR
PLACING RESISTORS IN SERIES INCREASES TOTAL RESISTANCE.
PLACING RESISTORS IN PARALLEL DECREASES TOTAL RESISTANCE

REVISION QUESTIONS

1. *What is a potentiometer?*
2. *Why are potentiometers used in amplifiers?*
3. *Draw a circuit containing 5 resistors in series.*
4. *How would the total resistance of your circuit compare to the resistance of any one resistor in the circuit?*
5. *A torch has a switch which when turned on makes the torch dim by limiting current to the bulb. The circuit involves a resistor. Can you draw a circuit with a switch to dim a bulb when the switch is turned on?*
6. *What is the resistance of these three resistors in series? 4K7, 2K2 and 3K9.*
7. *Draw a circuit to show three resistors in parallel.*
8. *How would the total resitance of this circuit compare to the total value of any resistor in the circuit?*
9. *What is the resistance of six 1K2 resistors in parallel?*
10. *The lights on Christmas trees are often wired in series. What would be the effect of one light bulb "blowing"?*



POT PLANT



LIGHT - DEPENDENT
RESISTORS

MAGNETS

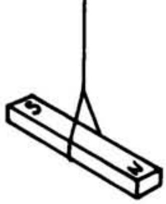
The photo shows some different types of permanent magnets. Magnets play an important part in the working of many electronic devices such as earphones, speakers and buzzers.

PERMANENT MAGNETS

Permanent magnets need no outside electricity to generate their magnetism. Magnets have certain points, called the magnetic poles, which seem to be where metals like iron nickel and cobalt are attracted most strongly.

E Check a magnet to see which metals it will attract. Try silver and copper coins, iron nails, aluminium foil and other common metals. This experiment will also show you where the magnetic poles are on the magnet.

E Try suspending a bar magnet from a length of fine cotton thread.



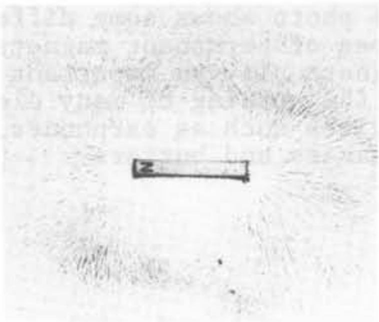
You should find that one pole of the magnet points North and the opposite pole of the magnet points South. You have made a model compass!

MAGNETIC FIELDS AND HOW TO MAP THEM

You will have noticed how strong magnets attract iron filings from some distance. The magnet seems to be able to pull on the iron filings even though there may be considerable separation between the magnet and the filings. To explain this "action at a distance" effect we say the magnet is surrounded by a magnetic field. The magnetic field is the area of influence of a magnet.

To map out the magnetic field, iron filings or small compasses may be used.

E



Iron filings can be sprinkled onto a cardboard sheet over a magnet.

They should form a pattern showing the magnetic field of the magnet.

E

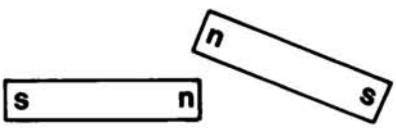
Compasses can be arranged around the magnet.

Notice the way the compass needles tend to line up in a pattern that shows the magnetic field.

The photos show the result of experiments plotting magnetic fields. Notice how the magnetic field seems to consist of a series of magnetic lines. The lines map out a pattern that starts at the North pole and ends at the South pole. Notice that the magnetic lines do not cross.

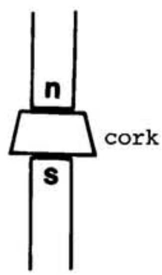
MAGNETS WITH MAGNETS

Magnets will exert strong forces on other magnets.



Two poles repelling

Two poles attracting



The Law of Magnets ** Unlike poles - Attract

** Like poles - Repel

MAGNETS ATTRACT IRON, NICKEL and COBALT

ALL MAGNETS HAVE TWO POLES - NORTH and SOUTH

AROUND A MAGNET IS A MAGNETIC FIELD

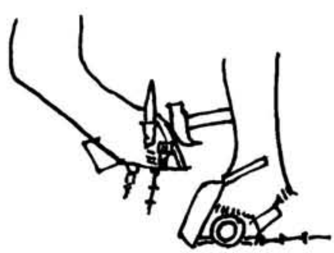
MAGNETIC FIELDS CAN BE MAPPED WITH IRON FILINGS OR COMPASSES

LIKE MAGNETIC POLES REPEL

UNLIKE MAGNETIC POLES ATTRACT

REVISION QUESTIONS

1. *What is a permanent magnet?*
2. *What are magnetic poles?*
3. *Name some metals that a magnet will attract.*
4. *What names do we give to the two poles of a magnet?*
5. *How does a compass work?*
6. *What is a magnetic field?*
7. *Tell of two ways that a magnetic field can be plotted.*
8. *What happens when the North pole of a magnet is held near the South pole of another magnet?*
9. *What is the Law of Magnets?*
10. *How could you tell which end of a plain bar magnet is the North pole using another magnet?*

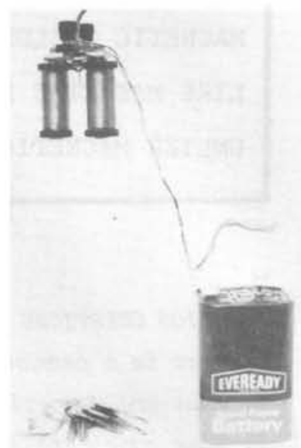


"WOULDN'T YOU THINK THEY'D HAVE FITTED ME WITH ORDINARY HORSESHOES !!!"

ELECTROMAGNETS

Electromagnets are a temporary magnet since they only become magnetic when they are supplied with electric current.

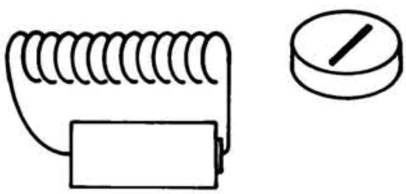
Notice that the electromagnet is made of many turns of insulated wire wound on a soft iron 'U' shaped bar. With current flowing it is a strong magnet but with no current it loses most of its magnetism.



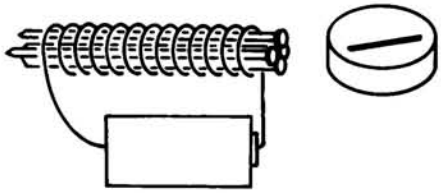
Complete circuit so current flows

Circuit is broken so no current flow

E It is easy to make an electromagnet. You can check its strength by seeing how well it attracts iron filings or by seeing how it deflects a compass needle.



Try first a simple wire coil with a single cell. Check with a compass to see if it deflects the needle. Do not leave coil connected for too long - it will use a lot of current and so will "flatten" the cell.



Now try some soft iron nails in the coil. Check the strength of the electromagnet now. Try it with some iron filings.

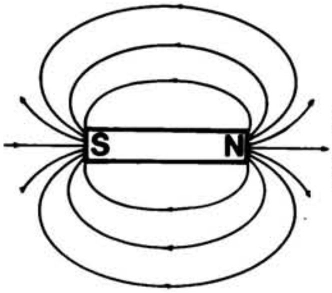
Try the electromagnet with many more turns of insulated wire.

If you have another torch cell try connecting it in series with the first. This will give more voltage and so will cause more current to flow.

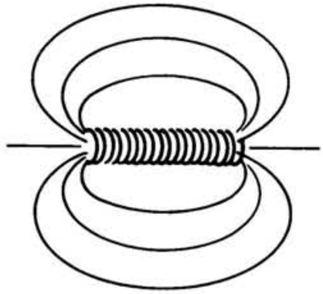
Did you find that we can make the magnetic effect of the electromagnet greater by :

* inserting an iron or ferrite core in the coil.
* increasing the number of turns of wire in the coil.
* causing more current to flow in the coil.

If a wire coil is operated as an electromagnet a check with compasses or iron filings shows a magnetic field similar to a magnet.

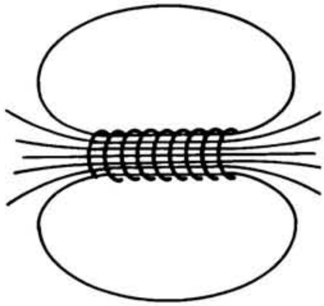


Field of permanent magnet

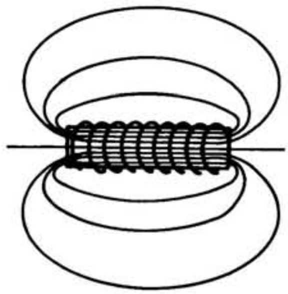


Field of a coil acting as an electromagnet

You may wonder how the ferrite or iron core increases the magnetic strength of a wire coil. The ferrite or iron tends to concentrate the magnetic field within the coil. The ferrite and iron are said to be highly permeable to magnetism.



Air spaced wire coil

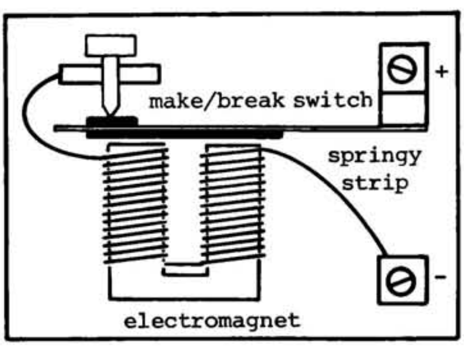


Similar coil with permeable core-

Concentrated magnetic field

USES OF ELECTROMAGNETS

1. The Buzzer



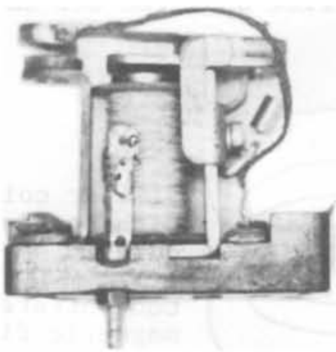
Think about how the buzzer operates:

* the current flows via the make and break switch and the springy strip energising the electromagnet,
* this will pull the metal strip down which opens the make and break switch,
* this allows the strip to spring up renewing the contact and so the cycle repeats and the strip "buzzes".

2. Headphones

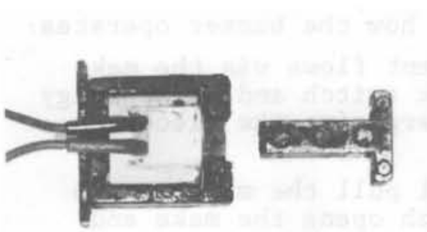
Notice the electromagnets inside the headphone (earphone). These have a permanent magnet in them. The permanent magnet attracts the thin sheet of metal (diaphragm). When changing or alternating electricity is supplied to the electromagnet the electromagnet sometimes strengthens the magnetism of the permanent magnets. This pulls the diaphragm down further. If the electromagnet opposes the magnetism of the permanent magnet the tension on the metal diaphragm is reduced. Thus alternating electric currents cause the diaphragm to move or to vibrate creating sound.

3. Electrical Relays



When electricity flows through the magnetic coil (solenoid) in the relay the metal armature is attracted. This causes metal contacts to open and close. The relay is like a remote switch controlled by a single circuit.

4. Solenoid



The photo shows a hollow electromagnet and a core of iron. When the electromagnet becomes magnetic because of current flow the core is attracted to the electromagnet. This type of device is called a solenoid and is used to activate hot/cold water taps in washing machines and dish washers.

ELECTROMAGNETS ARE ONLY MAGNETIC WHEN CARRYING AN ELECTRIC CURRENT

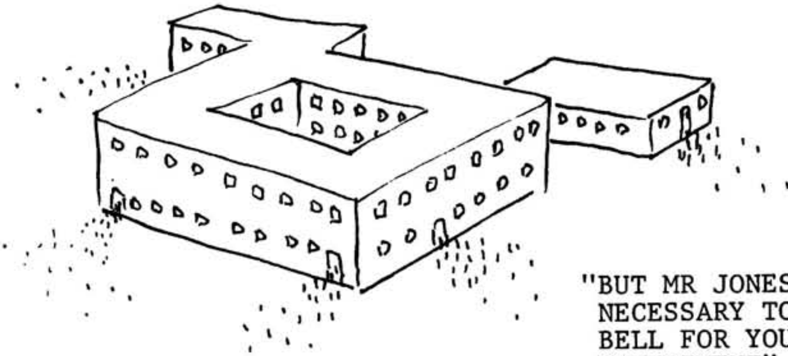
A COIL OF WIRE CARRYING AN ELECTRICAL CURRENT HAS A MAGNETIC FIELD

THE MAGNETIC EFFECTS OF THE COIL CAN BE INCREASED BY HAVING MORE TURNS, MORE CURRENT OR A SOFT IRON ROD

RELAYS, EARPHONES AND BUZZERS ALL USE ELECTROMAGNETS

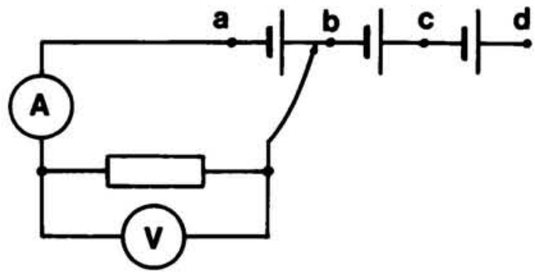
REVISION QUESTIONS

1. *Why are electromagnets called temporary magnets?*
2. *How would you make an electromagnet?*
3. *Why should the wire used to make an electromagnet be insulated?*
4. *How can a compass be used to check the strength of an electromagnet?*
5. *How can the magnetic effect of an electromagnet be made greater?*
6. *Draw the pattern of the magnetic field around an operating electromagnet.*
7. *What does "permeable core" mean about an electromagnet?*
8. *How does the "make and break switch" help a buzzer to operate?*
9. *Explain exactly how the electromagnet can convert variations in current to sound.*
10. *Draw a simple diagram and label it to explain the operation of a relay.*



"BUT MR JONES WAS IT REALLY NECESSARY TO USE THE SCHOOL BELL FOR YOUR ELECTROMAGNETISM EXPERIMENT"

VOLTAGE AND CURRENT



Note that:

* the cells form a series battery

* the ammeter is in series with the load resistor and measures the current

* the voltmeter is in parallel with the load resistor and measures the electrical push or voltage

* if the wire is moved to point B then C and D extra voltage would be applied with each move

Some typical results

Current	0	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	amperes
Voltage	0	$1\frac{1}{2}$	3	$4\frac{1}{2}$	volts
Resistor	cold	cool	warm	hot	

There are really no surprises here - since voltage represents electrical push or pressure on electrons and current indicates flow rate of electrons, you would expect that with higher voltage (push) you would get larger current (flow).

Notice that as the voltage doubles the current doubles too
e.g. voltage $1\frac{1}{2}$ changes to 3
current $\frac{1}{4}$ changes to $\frac{1}{2}$

Another way of noting this is to say that the ratio of voltage to current in a circuit is a constant (a constant number). Check the ratio by some simple calculations.

MATHS HINT - when dividing a number by a fraction simply invert (turn upside down) the fraction and multiply

Now the ratio

First ratio $\dfrac{1\frac{1}{2} \text{ volts}}{\frac{1}{4} \text{ ampere}} = 1\frac{1}{2} \times \frac{4}{1} = \frac{3}{2} \times \frac{4}{1} = \frac{12}{2} = 6 \ \frac{\text{volts}}{\text{amperes}}$

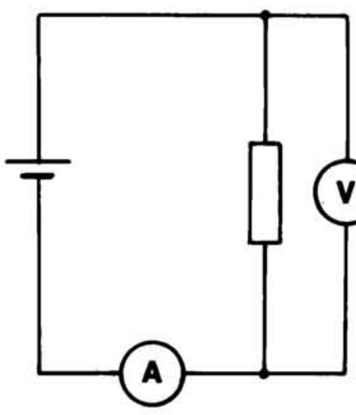
ANOTHER MATHS HINT - note that $1\frac{1}{2}$ is equal to $\frac{3}{2}$. This really says that $1\frac{1}{2}$ is equal to 3 halves or $3 \times \frac{1}{2}$ or $\frac{3}{2}$.

Next ratio $\dfrac{3 \text{ volts}}{\frac{1}{2} \text{ ampere}} = 3 \times \frac{2}{1} = \frac{3}{1} \times \frac{2}{1} = \frac{6}{1} = 6 \dfrac{\text{volts}}{\text{amperes}}$

Last ratio $\dfrac{4\frac{1}{2} \text{ volts}}{\frac{3}{4} \text{ ampere}} = 4\frac{1}{2} \times \frac{4}{3} = \frac{9}{2} \times \frac{4}{3} = \frac{36}{6} = 6 \dfrac{\text{volts}}{\text{amperes}}$

Note that the ratio of voltage to current in a resistive circuit is a constant. This was originally stated by George Simon Ohm in the form "the ratio of the potential difference between the ends of a conductor to the current flowing in it bears a constant number".

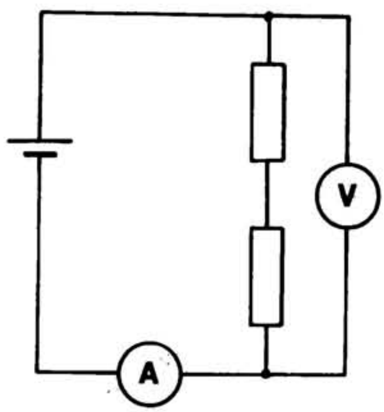
It is interesting to see how this constant ratio of voltage to current changes in circuits with different resistances.



Circuit I - single resistor

Typical results:
Voltage - $1\frac{1}{2}$ volts
Current - $\frac{1}{2}$ ampere

$$\text{Ratio} = \frac{\text{Voltage}}{\text{Current}} = \frac{1\frac{1}{2}}{\frac{1}{2}} = \frac{3}{2} \times \frac{2}{1} = \frac{6}{2} = 3$$



Circuit II - two resistors

Typical results:
Voltage - $1\frac{1}{2}$ volts
Current - $\frac{1}{4}$ ampere

$$\text{Ratio} = \frac{\text{Voltage}}{\text{Current}} = \frac{1\frac{1}{2}}{\frac{1}{4}} = \frac{3}{2} \times \frac{4}{1} = \frac{12}{2} = 6$$

ANOTHER MATHS HINT - When dividing by a number like 10 or 100, 100 000 simply move the decimal place of the number being divided to the left one place for every 0 in the dividing number.

Recalculating current $= 250 \text{ mA} = \frac{250}{1000}$ amperes

Dividing by 1 000 shift decimal place 3 places to left.

$$\frac{250}{1000} = \frac{250.}{1000} = .250 \text{ amperes}$$

Now back to the main calculation -

$$R \text{ Resistance (ohms)} = \frac{E \text{ voltage (volts)}}{I \text{ current (amps)}}$$

$$= \frac{1.5 \text{ volts}}{.25 \text{ amperes}}$$

YET ANOTHER MATHS HINT - When dividing by fractions move the decimal point on the dividing number to make it a whole number - then move decimal point on the other number an equal number of places.

$$\text{So Resistance} = \frac{1.5 \text{ volts}}{.25 \text{ amperes}}$$

$$= \frac{150}{25}$$

$$= 6 \text{ ohms}$$

Think about these results - they are quite reasonable. Comparing the two circuits the second circuit has :

SAME VOLTAGE	but	LARGER RESISTANCE	so	MORE OPPOSITION TO CURRENT	thus	LESS CURRENT

Notice how the second circuit with larger resistance also has a larger constant ratio number. This constant ratio number actually indicates the circuit resistance.

If the voltage is calculated in volts and the current in amperes the constant is defined as the resistance (measured in ohms).

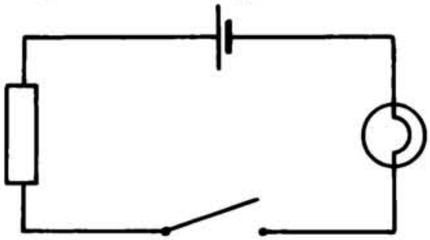
In symbols

$$\frac{E \text{ (emf) volts}}{I \text{ (current) amperes}} = R \text{ resistance (ohms)}$$

Thus to take the simplest case, an emf of one volt will cause a current of one ampere to flow in a resistance of one ohm.

Some examples of these laws.

Making a bulb brighter

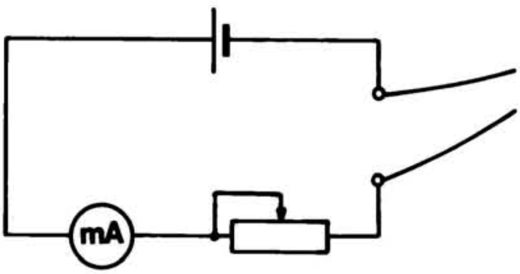


The diagram shows a simple bulb and resistor circuit. How can we make the bulb brighter? The brightness of the bulb depends on the current. We need to increase the current. To increase the current we could:

* use a battery of a higher voltage (greater voltage with the same resistance will mean a greater current).

* decrease the resistance in the circuit (with the same voltage a decreased resistance will mean a greater current).

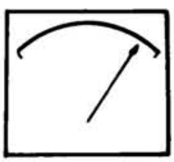
Making a simple circuit tester



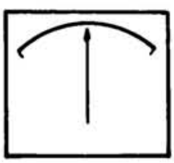
The meter is a sensitive current meter (say 1 mA FSD - one milliampere causes the meter to read full scale or full scale deflection).

Note that if the test leads are shorted together the meter can be set to read full scale by adjusting the variable resistor to allow just 1 mA to flow.

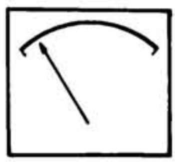
Now the meter can be used to check the resistance of circuits.



Means maximum current therefore low resistance in circuit being tested



Medium current therefore medium resistance in circuit being tested



Low current therefore high resistance in circuit being tested

Trying out some mathematical problems.

In a car the headlights operate at a PD of 12 volts with a current flow of 4 ampere . We can now find the resistance of the bulb.

We know that E = emf = 12 volt

I = current = 4 ampere

and $R = \frac{E}{I} = \frac{12}{4} = 3$ ohms.

The bulb has a resistance of 3 ohms. This of course is its operating resistance. Since most resistors change their resistance when hot its cold resistance would be different.

It is possible to find the power of the headlights.

We know that Power (P) = E (emf) x I (current)

= 12 volts x 3 ampere

= 36 watts

Thus the bulb produces both heat and light at a power output of 36 watts.

Another simple problem.

A small torch bulb when operated from a 1½ volt cell draws a current of 250 mA. What is resistance of bulb?

We know that the voltage is 1½ volts and the current is 250 mA but we must convert to the correct units.

MATHS HINT - Fractions can be converted to decimals by simply dividing the top number (numerator) by the bottom number (denominator)

So emf in volts = $1\frac{1}{2} = \frac{3}{2}$ volts

= 1.5 volts

And current in ampere = 250 mA

$= \frac{250}{1000}$ ampere

= .25 ampere

You may have noticed in the original experiment that the resistor became warm. This simply indicates that electrical energy is being converted to heat energy.

However with more current and voltage more heat was produced. It is more correct to say that with increased current and voltage the rate of heat production was greater. The actual rate of heat production - the heat power - can be predicted, using the equation

Heat power (watts) = Voltage (volts) x Current (amperes)

Notice that this equation agrees with the earlier results. When the voltage and the current are high the heat power developed in the resistor will also be high.

Check the power developed in the resistor when the wire is:

at B Power = E x I

$$= 1\tfrac{1}{2} \times \tfrac{1}{4} = \frac{3}{2} \times \frac{1}{4} = \frac{3}{8} \text{ watt}$$

at C Power = E x I

$$= 3 \times \tfrac{1}{2} = \frac{3}{1} \times \frac{1}{2} = \frac{3}{2} = 1\tfrac{1}{2} \text{ watts}$$

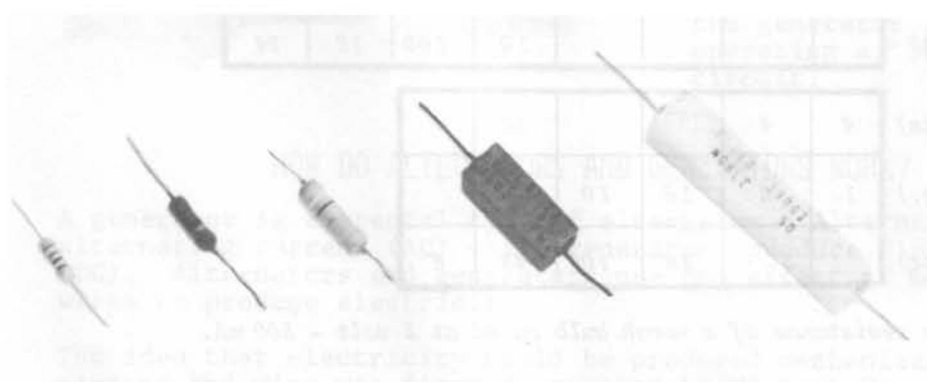
at D Power = E x I

$$= 4\tfrac{1}{2} \times \frac{3}{4} = \frac{9}{2} \times \frac{3}{4} = \frac{27}{8} = 3\frac{3}{8} \text{ watts}$$

This formula will allow you to calculate the heat power developed in resistors. Most resistors are rated according to the power they can dissipate or "lose into the air" safely.

Small resistors are often rated at one eighth watt - this means the resistors will dissipate up to one eighth watt of heat power without becoming excessively hot.

The photo shows a selection of resistors.



¼ watt ½ watt 1 watt 5 watt 10 watt

IN A RESISTANCE CIRCUIT GREATER VOLTAGES MEAN GREATER CURRENT

IN A RESISTANCE CIRCUIT THE RATIO OF VOLTAGE TO CURRENT IS A CONSTANT

THIS CONSTANT INDICATES THE RESISTANCE IN THE CIRCUIT

$$\frac{E}{I} = R$$

HEAT POWER DEVELOPED IN A RESISTOR IS MEASURED IN WATTS

HEAT POWER = EI

REVISION QUESTIONS

1. *In a simple circuit what must happen to the current when the voltage doubles?*
2. *In a simple resistive circuit what two quantities form a constant ratio?*
3. *What is Ohms Law?*
4. *What is the simple maths rule about dividing numbers by 10 or 100 or 1 000?*
5. *What do these symbols stand for? R, E, I and P.*
6. *What are the units for the quantities mentioned in Q5?*
7. *What is the mathematical connection between (a) R, V and I ?*
   (b) P, V and I ?

Use these equations or rules to find the missing quantities.

8.

V (volts)	2	4	1	20			8	2
I (amps.)	2	2	2	2	2	2		
R (ohms)					10	100	16	. 24

9.

V (volts)	4	4			24	
I (amps.)	1	2	16	10		
P (watts)			16	100	48	6

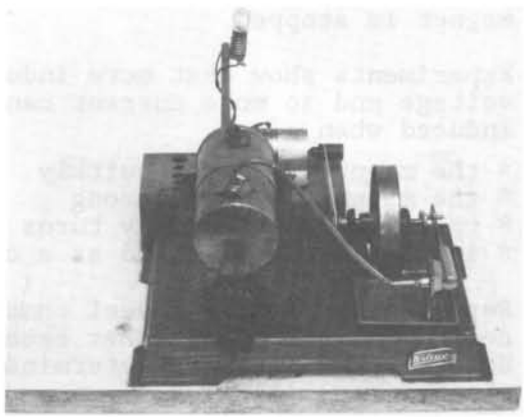
10. *Find the resistance of a torch bulb rated at 3 volt - 500 mA.*

GENERATING ELECTRICITY

We know that electricity can be produced using chemical energy stored in the familiar electrical cells and batteries. However the electricity supplied to domestic housing, industry and electric rail systems is not produced from large batteries. Electricity in such large quantities is made mechanically by driving electrical alternators or generators which produce electricity by the interaction of magnetic fields.

The photo shows a model power station. Alcohol is used to heat water in the boiler to make steam. The steam is used to run a small engine. This spins a small alternator via a rubber band. The alternator produces electricity to light a small torch bulb.

Most of our power stations use coal as a fuel. Hydro electric power stations use the energy of running water to drive the alternator.



E Try using a small electric motor as a generator. Many will generate electricity when the motor is spun by hand.

Use a low voltage torch bulb.

Try spinning the motor by hand with the bulb disconnected to feel the difference in load when the generator is not operating a "load" circuit.

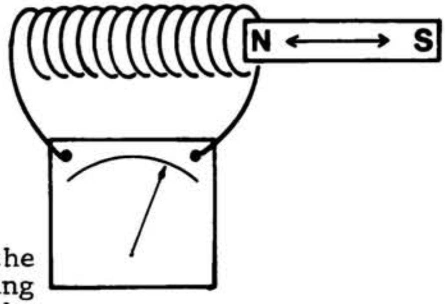
HOW DO ALTERNATORS AND GENERATORS WORK?

A generator is a special type of alternator. Alternators produce alternating current (AC) while generators produce direct current (DC). Alternators and generators use the effect of magnetism and wires to produce electricity.

The idea that electricity could be produced mechanically using magnets and wire was first discovered by Michael Faraday.

E

The diagram shows a simple experiment for inducing or generating electricty



As the magnet moves into the coil the meter shows that electricity is being generated. No current flows when the magnet is stopped.

Experiments show that more induced voltage and so more current can be induced when :

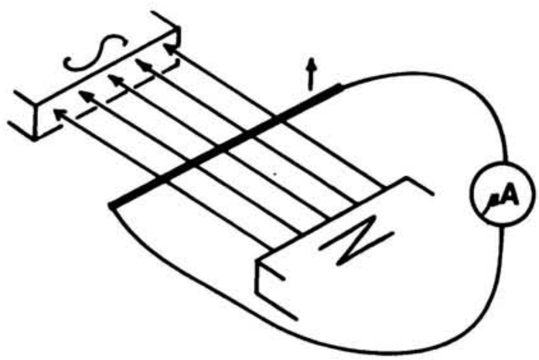
* the magnet is moved quickly
* the magnet is very strong
* the wire coil has many turns
* iron or nickel is used as a core for the coil.

Further experiments reveal that it does not matter which is moved coil or magnet. In either case electricity is induced - but the direction of movement determines in which direction the induced electricity will flow.

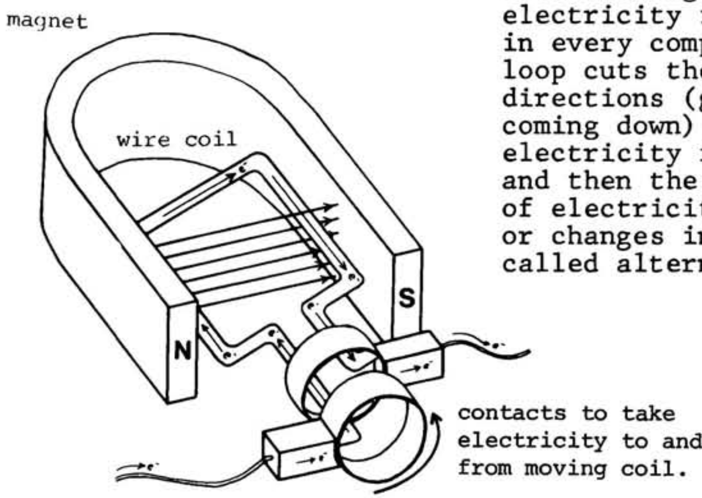
To help understand the generation of induced electricity the idea of a magnetic field is used.

The diagram shows how as the wire cuts through the magnetic field electricity is induced in the wire. The induced voltage can be made greater by increasing the rate of cutting of the magnetic field. This can be done by:

* moving the wire faster.
* having a stronger magnet.
* having more lengths of wire in the field.
* concentrating the field.



AN ELECTRIC ALTERNATOR



As the wire loop turns, the wire cuts the magnetic field and so electricity is induced. However in every complete turn the wire loop cuts the field in two directions (going up and then coming down) and so the induced electricity flows first one way and then the other. This type of electricity that alternates or changes in direction is called alternating current or AC.

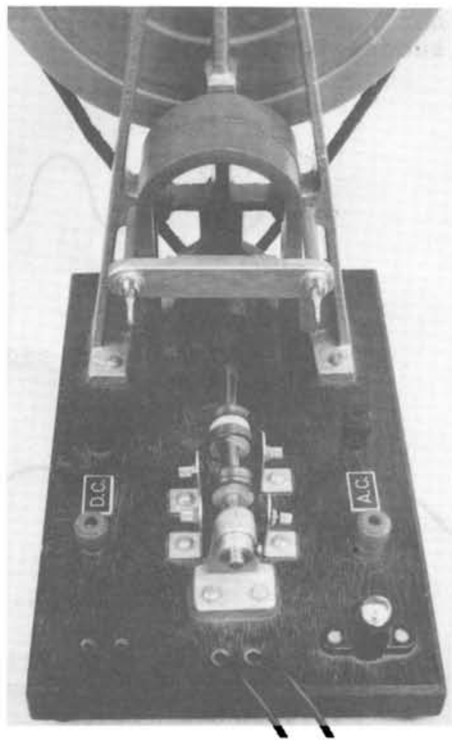
The photo shows a model alternator and generator unit.

It generates considerable electricty by having:

* many wire turns.
* strong magnets creating a strong magnetic field.
* a soft iron core to concentrate the magnetic field.
* a set of pulleys to achieve a high turning speed.

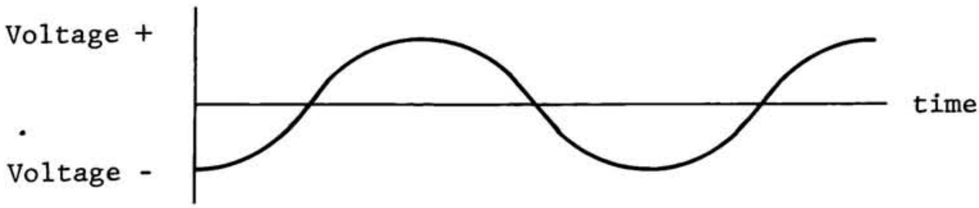
Note the rings and brushes to allow electricity to be transferred from the moving coil to the outside circuit.

By using special rings with separate segments the AC that the coil produces can be turned to current in one direction - direct current - DC.



ABOUT ALTERNATING CURRENT

A graph can be used to show the AC from an alternator.

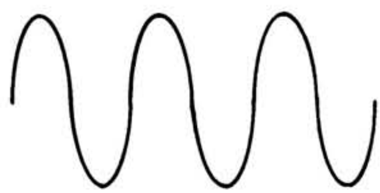


Notice how the graph shows that the voltage (and so the current) alternates in direction.

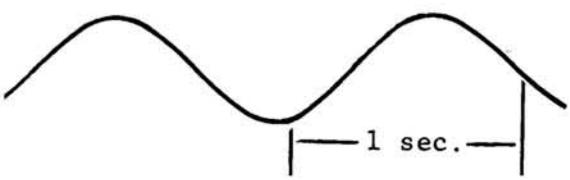
The variation of voltage with time is a smooth curve called a sine wave.

Sine waves are often drawn to represent AC. The "height" or amplitude of the curve indicates the voltage while the spacing of the troughs and crests indicates the time for a complete current cycle. Closely spaced crests and troughs mean a short time for a complete cycle, hence a rapid rate of change of direction of the electricity. Another way of saying this, is to say the alternating current has a high frequency - that is changes direction in rapid succession.

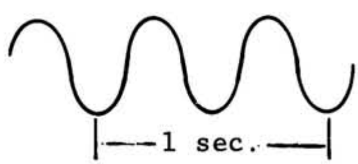
Small amplitude AC signal
Small voltage



Large amplitude AC signal
Larger voltage



Long time for one cycle
Small number of cycles per second
Low frequency



Short time for one cycle
Large number of cycles per second
Higher frequency

MECHANICAL ENERGY CAN BE CHANGED TO ELECTRICAL ENERGY USING AN ALTERNATOR OR GENERATOR

ALTERNATORS USE THE IDEA OF A CONDUCTOR CUTTING A MAGNETIC FIELD

ELECTRICITY MADE THIS WAY IS CALLED INDUCED ELECTRICITY

ALTERNATING CURRENT (AC) IS CURRENT WHICH REVERSES DIRECTION CONSTANTLY

ALTERNATING CURRENT CAN BE LIKENED TO A SINE WAVE

REVISION QUESTIONS

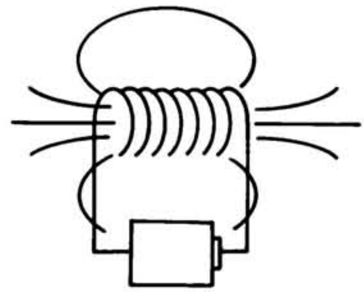
1. *What do the letters "AC" stand for?*
2. *What is the difference between AC and DC?*
3. *How could you induce an electric current in a coil of wire?*
4. *What factors affect the amount of induced electricity produced when using a coil of wire and a magnet?*
5. *Tell how a simple electric alternator produces electricity?*
6. *Why does the coil in an alternator produce AC and not DC?*
7. *Sketch a graph to depict a simple AC waveform.*
8. *What feature of the graph indicates the voltage of the alternating signal?*
9. *What does the closeness of the waves on your graph tell about the alternating signal?*
10. *A simple DC electric motor will usually act as a generator when the shaft is spun. What must be happening inside to produce the DC?*

ELECTROMAGNETIC INDUCTION

We have seen that when conductors cut magnetic fields, induced electricity is generated. It is the movement between the magnetic field and the wire, which generates the electricity. Can the magnetic field be "moved" without actually moving the magnet? - or without a magnet at all?

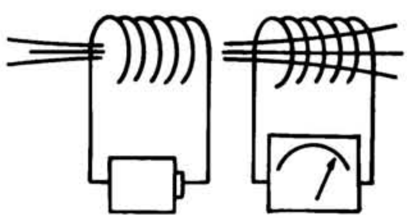
Check this electromagnet :

No current
no magnetic field

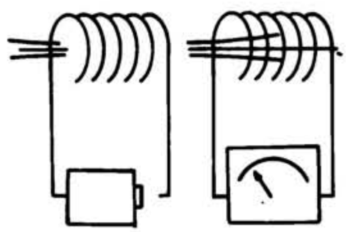


Current flows
magnetic field

Clearly the field must "grow" or "form" in space as the switch is closed. This field growth is really a type of field movement and it can induce electricity in another conductor. This type of induction of electricity is termed electromagnetic induction.



As the switch closes
current flows.
A magnetic field grows
rapidly, enveloping the
wire on the other coil -
electricity is induced
and detected on
sensitive electric
meter



As the switch opens
current stops.
Magnetic field
collapses, interacting
with the wire on the other
coil as it does so -
electricity is induced
and detected on
sensitive electric meter.

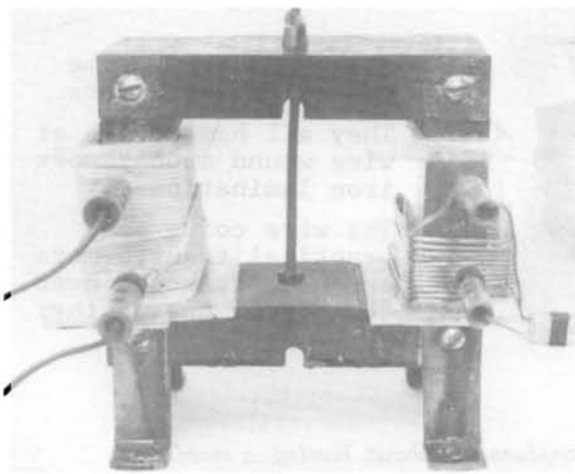
Some important points to notice :

1. only a <u>changing</u> field will effectively cut the second coil and so induce electricity.

2. thus only when the current flow changes, will induced electricity be formed.

3. the direction of the induced electric current depends on the direction of movement of the magnetic field. Thus an expanding field at current turn on, will induce current in an opposite direction to the contracting field at current turn off.

4. the first coil (which carries incoming electricity) is called the primary while the second coil (which carries the induced electricity) is called the secondary coil.



The idea of a changing current in magnetic coil, inducing electricity in another coil, is used in transformers.

A model transformer is shown in the photo.

Notice how the two coils of wire surround the one soft iron core. This core is made of many separate thin sheets of iron called laminations. These laminations magnetically link the primary to the secondary - that is they ensure that the maximum primary magnetic field (of the primary coil) effectively cuts all the windings of the secondary, as it develops and collapses.

The iron core magnetically links the primary to the secondary - it ensures that the changing field of the primary intersects the secondary winding with minimum losses.

To ensure a changing field, rather than switching DC on and off the primary is supplied with AC - this ensures a varying magnetic field. The field smoothly grows to reach maximum strength then gradually reduces to zero. It then builds up in the reverse and again returns to zero. This process repeats itself each AC cycle.

Transformers are used to transform voltages. For instance in a transformer with twice as many turns on the secondary as on the primary the secondary output voltage is twice the primary input voltage.

CHANGING MAGNETIC FIELDS INDUCE ELECTRICITY IN CONDUCTORS

CHANGING CURRENTS CAUSE CHANGING MAGNETIC FIELDS

USING A CHANGING CURRENT IN A COIL TO INDUCE ELECTRICITY IN ANOTHER COIL IS CALLED ELECTROMAGNETIC INDUCTION

TRANSFORMERS USE COILS MAGNETICALLY LINKED

The photo shows some typical transformers.

They all have coils of wire wound around soft iron laminations.

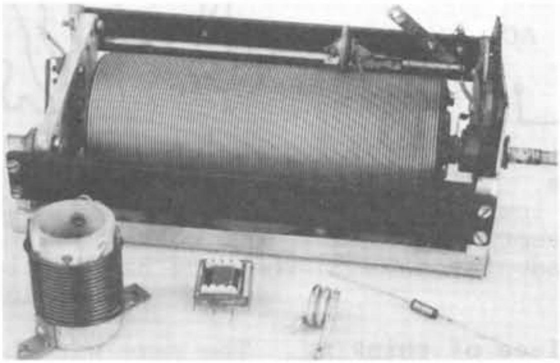
The wire coils on practical transformers are usually wound over the top of one another.

REVISION QUESTIONS

1. *How can induced electricity be produced without having a moving magnet?*
2. *What happens to the magnetic field around an electromagnet when the current is switched off?*
3. *Describe the magnetic field around an electromagnet supplied with AC.*
4. *What does "electromagnetic induction" mean?*
5. *How could you build a model transformer using some lengths of wire and a soft iron nail?*
6. *What are the essential parts in a transformer?*
7. *What is the difference between primary and secondary windings?*
8. *How do the iron laminations help a transformer operate?*
9. *Why will transformers not operate with DC?*
10. *How does the number of turns on the primary and secondary windings affect the voltage produced by a transformer?*

INDUCTORS

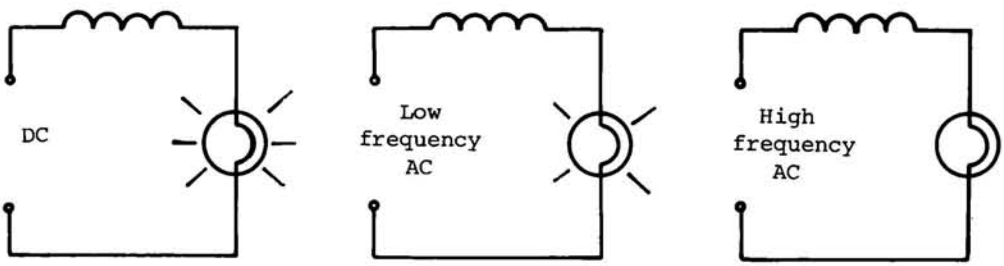
A glance in a radio receiver will reveal components that resemble simple magnetic coils. They consist of a coil of wire, often with a ferrite centre to improve the magnetic effect. Such devices are called inductors. Inductors are often called chokes or coils.



All of the components in the photo are called inductors.

The symbol for an inductor is:

The diagram shows a typical inductor wired in some different circuits. The current is direct in the first and alternating in the next two but the voltage is at a constant effective level in each circuit.

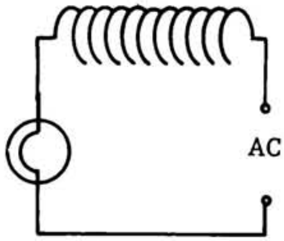


Bulb is bright	Bulb is dim	Bulb is very dim
For DC, inductor is acting as a conductor	For low frequency AC, inductor is acting as a slight resistance	For high frequency AC, inductor is acting as a high resistance

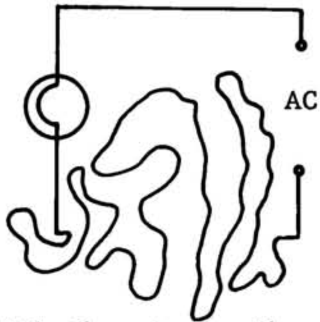
Notice that the coil which is a good conductor for DC acts as a resistance to AC. We say that the coil is acting as an inductance and has not resistance but reactance. We use the word reactance because the opposition to current depends on frequency. At higher frequencies the opposition or reactance is greater than at lower frequencies.

WHY DO COILS HAVE INDUCTANCE AND SO HAVE REACTANCE ?

An interesting experiment



With the wire in a coil-
The bulb is dim.
The current is low.
The coil has reactance to AC.
The coil has inductance.



With the wire coil unwound-
The bulb is bright.
The current is high.
The wire has low reactance
The wire has little inductance.

This is an important piece of thinking. The same wire has a larger inductance when wound in a coil. Could inductance be related to magnets, generators and induced electricity?

To induce electricity a changing magnetic field must cut a conductor in a circuit. Could this be happening in the coil? Think it through. In the coil some AC must be flowing. This will cause a changing magnetic field. This field must be cutting the turns of wire in the coil which must be inducing some electricity. This induced electricity will oppose the incoming current so the total current will rise and fall slowly in the coil. The effect of this is to have a reduced current which we explain by saying the coil has reactance to AC.

With the coil unwound the changing magnetic field does not effectively intersect the wire coil so there is little induced electricity to oppose the incoming electricity. So we say the wire has little reactance to AC.

For the maximum inductance a coil or inductor should have

* many turns
* ferrite or soft iron core
* large diameter
* short length

These factors all act to increase the amount of the induced electricity which opposes the incoming electricity, so giving the coil maximum reactance.

WHAT ARE THE UNITS OF INDUCTANCE?

Inductance is usually indicated by the letter L and is expressed in henrys (H). An inductance of 1 henry is a very large one so a series of smaller units is usually used.

milli henrys (mH) 1 000 mH = 1H
micro henrys (μH) 1 000 000 μH = 1H

Thus HENRYS are bigger than MILLI HENRYS are bigger than micro henrys

Remember that

1 000 μH = 1 mH

IMPEDANCE

In our thinking about inductors opposing AC we have always imagined the wire itself to be a perfect conductor. In practice this is not so. A large value inductance may have thousands of turns of fine wire. This wire obviously will have a small resistance. Thus the inductor will oppose AC in two ways. Firstly due to the reactance of the coil and secondly due to the resistance of the coil. This total opposition to the incoming AC is called impedance.

IMPEDANCE = Opposition to AC due to resistance of wire with Opposition to AC due to reactance of windings

For example a speaker may be marked "impedance 16 ohms". This means for AC at audio frequencies the total resistance and reactance will be 16 ohms. Think about what that means:

* when supplied with AC the current will be limited to a reasonable value due to the impedance of the circuit

* if the speaker were supplied with DC the current would be much higher due to opposition by the circuit resistance only

* if the frequency of the applied AC was increased the impedance would increase since although the resistance would not change, the reactance would become greater.

WIRE COILS HAVE INDUCTANCE

IN AN INDUCTOR A CHANGING CURRENT PRODUCES A CHANGING INDUCED CURRENT WHICH OPPOSES THE INCOMING CURRENT

IN AN INDUCTOR THE OPPOSITION TO AC IS TERMED REACTANCE

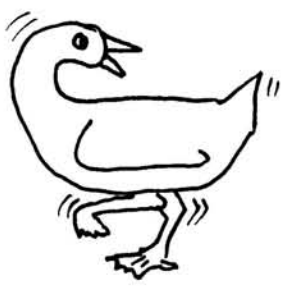
AT HIGHER FREQUENCIES COILS HAVE GREATER REACTANCE

THE UNIT OF INDUCTANCE IS THE HENRY

IMPEDANCE IS OPPOSITION TO AC DUE TO BOTH REACTANCE AND RESISTANCE

REVISION QUESTIONS

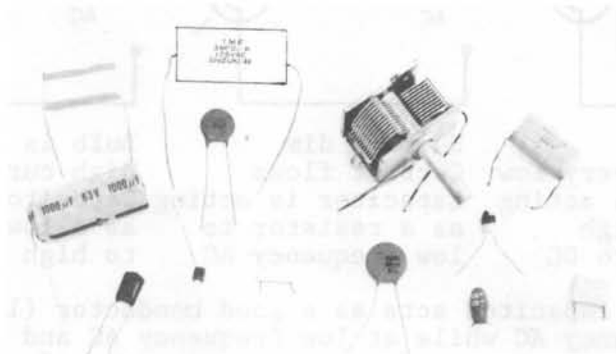
1. *How could you recognise inductors in a radio or a television?*
2. *What is the symbol for an inductor?*
3. *Do inductors act as conductors to AC or DC?*
4. *Do inductors tend to block or pass AC?*
5. *What does reactance mean?*
6. *How does the reactance of an inductor vary as the frequency of the applied AC is increased?*
7. *Why do inductors oppose AC?*
8. *How could the inductance of a simple inductor, formed from two turns of wire wound around a pencil, be increased?*
9. *What are the units of inductance?*
10. *What is impedance?*



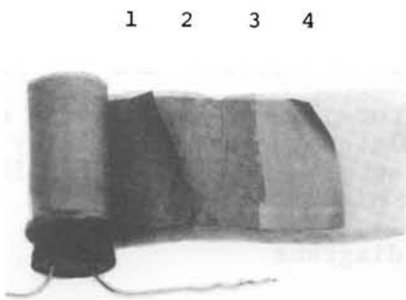
OH, YOU SAID <u>INDUCTANCE</u>.

CAPACITORS

Capacitors are components frequently found in electronic devices and come in a variety of shapes and sizes.



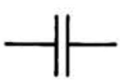
Despite the variety of size and shape, capacitors all consist of two conductors separated by an insulator. This insulator is termed the dielectric.



An opened electrolytic capacitor.

1. conductor (aluminium foi
2. dielectric (paper)
3. other conductor
4. paper insulator

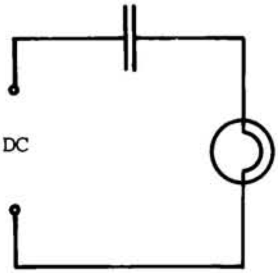
The symbols for capacitors are shown below.



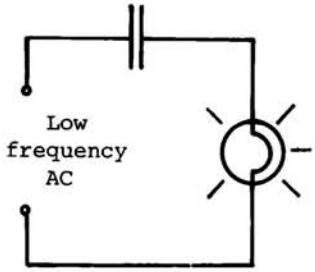
fixed capacitor

variable capacitor

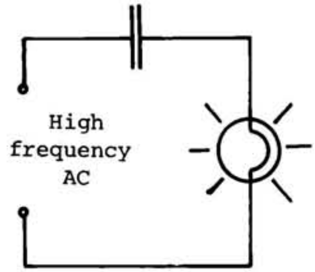
Now think about how a capacitor performs in some different circuits. The current is direct in the first and alternating in the next two but the voltage is at constant effective level in each.



Bulb is out
Current is very low
Capacitor is acting as a very high resistance to DC



Bulb is dim
Current flows
Capacitor is acting as a resistor to low frequency AC



Bulb is bright
High current flow
Capacitor is acting as a low resistance to high frequency AC

Notice that the capacitor acts as a good conductor (low "resistance") to higher frequency AC while at low frequency AC and DC the capacitor acts as a high resistance. Since the resistance of the capacitor changes with the frequency of the current we say the capacitor has reactance.

Remember the rule - at higher frequencies the opposition to current (the reactance) is lower than at low frequencies.

WHY DO CAPACITORS TEND TO "PASS" HIGH FREQUENCY AC?

Since capacitors have an insulating dielectric between their conductive plates the fact that they act as a very high resistance to DC is no surprise. Then how is it that they have a low reactance to high frequency AC?

Check these diagrams

When the electrons flow onto one end of the capacitor, electrons on the opposite plate are repelled away into the circuit

When the electron flow is reversed, electrons flow onto the other plate and are repelled off the first plate

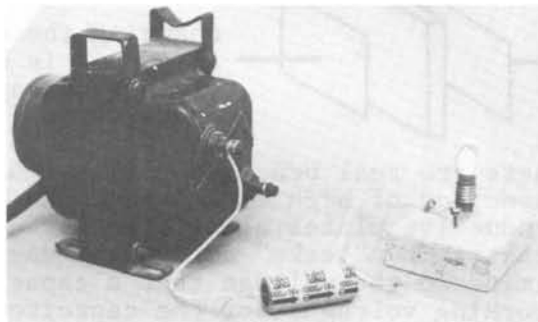
With AC in the circuit, the electrons surge on and off either plate, forcing by repulsion electrons on the other plate to move similarly

Thus with AC the changing direction of the electrons on the circuit can be kept up even though no electrons travel across the insulating barrier. This effect is more noticeable at higher frequencies of AC so we say that at these higher frequencies the reactance is lower.

TRYING DIFFERENT CAPACITORS IN AC CIRCUITS

The lamp is dim - this capacitor is passing a small alternating current. We say the capacitor has a small capacitance.

The lamp is bright - this capacitor is passing a large alternating current. We say the capacitor has a large capacitance.

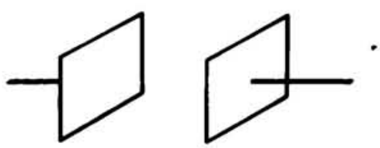


Thus the capacitance of a capacitor controls how much AC (at a particular frequency) it will pass. High capacitance capacitors will pass larger currents.

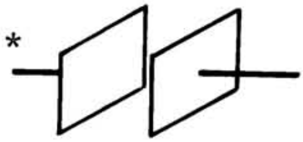
HOW CAN WE INCREASE CAPACITANCE?

The capacitance of capacitors is measured in Farads.

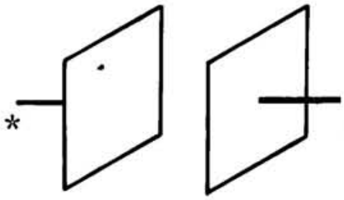
Think of a simple air spaced capacitor



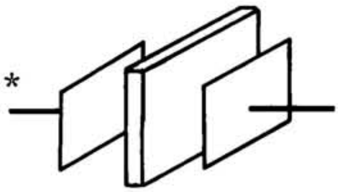
Its capacitance could be increased by:



bringing the plates closer together



making the plates bigger in area



changing the dielectric to a better material (e.g. oil is better than air and so a similar oil spaced capacitor would have more capacitance)

There are real practical limitations for capacitor design. A capacitor of high capacitance can be formed by bringing the two conductive plates close together but then we may find that electricity "leaks" across the very thin dielectric. There are limits to the voltage that a capacitor will stand. A safe voltage (working voltage) for the capacitor is normally mentioned on the capacitor.

A Farad is an extremely large unit. Most capacitors are marked in sub-units.

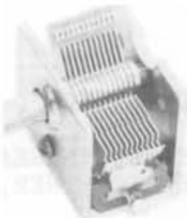
microfarads	(μF)	1 000 000 μF = 1F
nanofarads	(nF)	1 000 000 000 nF = 1F
picofarads	(pF)	1 000 000 000 000 pF = 1F

Thus MICROFARADS are bigger than NANOFARADS are bigger than picofarads

Remember that

1 000 nF = 1 μF
1 000 pF = 1 nF

LOOKING AT SOME PRACTICAL CAPACITORS



In this variable capacitor maximum capacitance occurs when the two sets of plates are closest together.

Dielectric	- air
Plates	- aluminium
Capacitance	- 40 to 415 picofarads
Working voltage	- several hundred volts

Electrolytic capacitors can have very high capacitance but are polarised. They have positive and negative terminals which must be wired to positive and negative sides of the circuit in which they are being used.

Dielectric	- chemical layer of oxide on plates
Plates	- aluminium foil
Capacitance	- to several thousand microfarads
Working voltage	- to several hundred volts

"Greencap" capacitors have their metal plates and dielectrics moulded in plastic

Dielectric	- polyethylene film
Plates	- metallised film
Capacitance	- 0.001 to 4.7 microfarads
Working voltage	- to thousands of volts

Ceramic capacitors are made of two flat discs of metal with a ceramic dielectric. They are used in high frequency applications and can be of high precision.

Dielectric	- ceramic
Plates	- metal discs
Capacitance	- 1 pF to 1 μF
Working voltage	- to thousands of volts

CAPACITORS ARE FORMED FROM TWO CONDUCTIVE PLATES SEPARATED BY AN INSULATOR

CAPACITORS TEND TO PASS AC BUT BLOCK DC

CAPACITORS HAVE A LOW REACTANCE TO HIGH FREQUENCY AC

THE CAPACITANCE OF CAPACITORS CAN BE INCREASED BY INCREASING SURFACE AREA OF PLATES, BRINGING PLATES CLOSER TOGETHER, OR BY USING SPECIAL DIELECTRICS

CAPACITANCE IS MEASURED IN FARADS

REVISION QUESTIONS

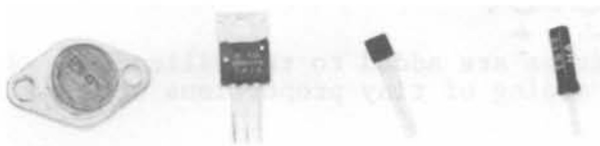
1. *What is a capacitor?*
2. *What is the correct name for the insulator in a capacitor?*
3. *Do capacitors pass or block DC?*
4. *Do capacitors have a high or low reactance to high frequency AC?*
5. *With a capacitor in an AC circuit does the reactance increase or decrease as the frequency of the AC increases?*
6. *Explain why capacitors pass AC but not DC?*
7. *What are the units for capacitance?*
8. *How could the capacitance of a simple air spaced capacitor be increased?*
9. *Which capacitor would have the lowest reactance?* *a. 10 microfarad.*
b. 1 microfarad.
10. *What does the term "working voltage" mean?*

COULD YOU SELL ME ONE
OF THOSE MICROBE - FARAD THINGS ?

SEMICONDUCTORS

You have seen in earlier chapters the idea of the metallic conductors of electricity being very different from the plastic and non metallic insulators. There are substances such as germanium and silicon which are part way between insulators and conductors. They are not resistors but semi-conductors since they are, in their pure state, insulators but when mixed with very small quantities of certain impurities the material may become quite conductive.

It has been the development and use of these semiconductor materials that has lead to the production of many of the electronic devices that we know today.



A range of modern transistors

Older style transistor

Hybrid Circuit

minature transistors and components moulded in a package

Small Scale Integration

tens of transistors to form timer/operational amplifier circuits

Large Scale Integration

contains hundreds of transistors forming a complex logic circuit

Medium Scale Integration

contains several separate logic circuits - up to a hundred transistors

Large Scale Integrated Circuits

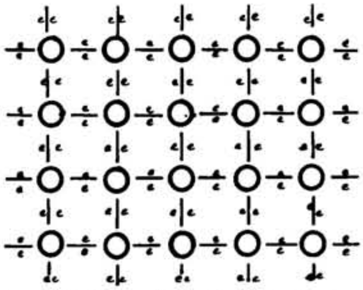
This LSI circuit has 16 000 high speed memory circuits - thousands of transistors

Very Large Scale Integrated Circuit

This VLSI circuit has thousands of transistors in a complex three dimensional circuit on a single crystal.

SEMICONDUCTORS - IMPURITIES AND DOPING

In pure silicon or germanium the electrons of the atoms are all effectively used to bond the atoms together. There are few "mobile" electrons which would allow the substances to conduct.



Every available electron in silicon is used to bond the atoms together. There are no "spare" electrons as in metals.

If certain impurities are added to the silicon, we change the situation. This adding of tiny proportions of impurity atoms is called "doping".

If we add tiny amounts of arsenic or phosphorus these atoms take the place of a few of the silicon atoms. We should take note of two effects:

(i) The material is still neutral. The numbers of electrons and positive charges are the same.

(ii) Some of the electrons are free to drift. Not all are tied up in holding the atoms together.

This is N-type material.

If we add tiny amounts of indium or gallium to the silicon some silicon atoms are replaced by these atoms. Again:

(i) The material is electrically neutral.

(ii) There are <u>places</u> available for electrons to hold the atoms together.

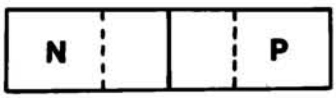
This is P-type material.

If we remove the "surplus" electrons from N-type silicon, it becomes positively charged.

If we add extra electrons to P-type silicon, it becomes negatively charged <u>but</u> these electrons are held - they are not free to drift.

THE DIODE

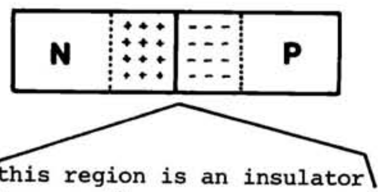
What happens if we "weld" together a piece of P-type and a piece of N-type silicon?



extra electrons from here drift to places available for them here

THIS CAUSES

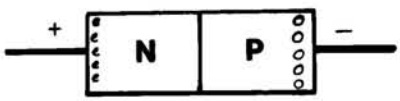
charged positive charged negative



this region is an insulator because there are no surplus electrons free to drift and no spaces to accept them.

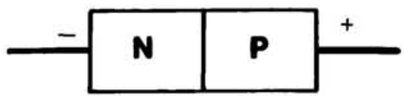
Now let us try putting the P-N junction in a circuit.

Try putting the N end of the junction to the positive end of the circuit



This junction will not conduct - the voltage has effectively separated the mobile electrons and the electron "holes"

Try putting the N end of the junction to the negative end of the circuit



This junction will conduct - the mobile electrons and mobile electron "holes" meet at the junction and current flows

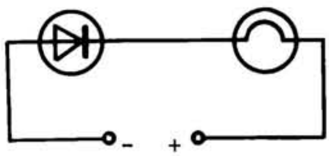
Thus the P-N junction acts as a one way valve. Current will only flow when the N end of the junction is made negative and the P end is positive. When the N end is positive and the P end is negative no current flows.

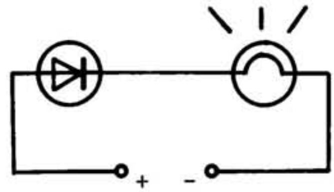
To be more exact we call the P end the anode and the N end the cathode. The junction conducts electrons from the cathode to the anode when the anode is more positive than the cathode. We say the diode is forward biased. If the anode is more negative than the cathode the junction, within limits, will not conduct and we say it is reverse biased.

This type of semiconductor which will allow current to flow in one direction is called a diode. Many diodes are simple junction types consisting of a simple P-N junction as shown in the diagrams.

Diodes come in a great variety of shapes and sizes. The diode has the general symbol of

The properties of diodes are clearly shown in the experiment below.





Lamp does not light because -

Current does not flow since -

Diode is reverse biased since -

The anode is more negative than the cathode

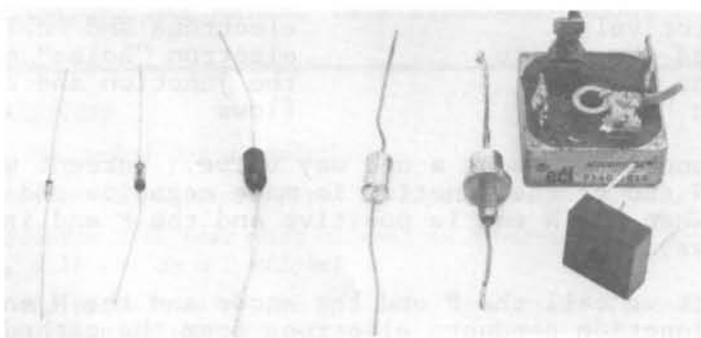
Lamp lights because -

Current flows since -

Diode is forward biased since -

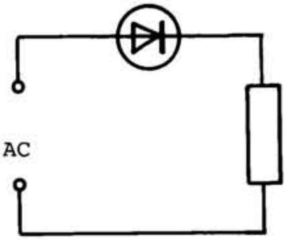
The anode is more positive than the cathode

The ability of diodes to effectively allow current to flow in only one direction is used in many electronic circuits.



A selection of diodes and diode bridges

Think of a diode in an AC circuit



In the supply, electrons flow in one direction then the other. The waveform shows this alternating current.

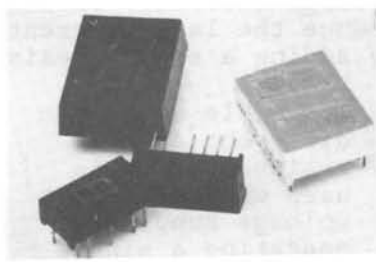
In the load, electrons flow at intervals but only in one direction. The waveform shows this pulsating direct current.

In effect the diode has converted the AC to a rough form of pulsating DC. We say the AC has been rectified to produce DC. The process is called rectification.

A special effect of some diodes is to emit light when they are conducting - these are the familiar light emitting diodes or LEDs.

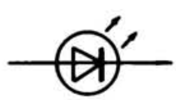
A photograph of some LEDs. The diagram shows the usual way of marking the cathode

short lead - by flattened edge of case is cathode



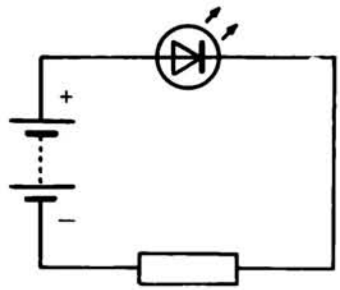
These devices contain many LEDs. By arranging for some LEDs to pass current and glow the shape of a number or letter is displayed.

standard symbol for a LED



ARRANGING LEDs IN CIRCUITS

A simple LED circuit



This circuit could be used to

* check which lead of the LED is the cathode - the LED will only glow when the cathode is wired to the negative side of battery supply

* check which terminal of a battery is negative - the LED will only glow when the negative terminal of battery is wired to the LED cathode

Notice the resistor in the circuit. This part of the circuit is a good application of the Ohms Law principle. The LED when forward biassed conducts electricity well - it is acting as a low resistance. With a voltage of 9 volts a low resistance will pass a large current. This large current will damage the LED. To reduce the large current the resistance of the circuit is increased by adding a series resistance in the circuit.

The table shows the different series resistances to be used with different voltage supplies operating a single LED

LIGHT EMITTING DIODES

Circuit voltage	Series Resistance for LED current, 10 and 30 mA.
1.5	82 - 0 ohms
3	220 - 76 ohms
4.5	390 - 120 ohms
6	560 - 180 ohms
9	820 - 270 ohms

GERMANIUM AND SILICON ARE SEMICONDUCTORS.

SEMICONDUCTORS ARE USED IN TRANSISTORS, DIODES AND INTEGRATED CIRCUITS.

SEMICONDUCTOR MATERIALS MAY BE DOPED TO PRODUCE N AND P TYPE MATERIALS.

DIODES CAN BE FORMED AT THE JUNCTION OF N AND P TYPE MATERIALS.

DIODES CONDUCT WELL WHEN FORWARD BIASED.

DIODES ARE RECTIFIERS OF AC.

SOME DIODES CAN EMIT LIGHT.

REVISION QUESTIONS

1. *Explain how semiconductor materials are different from insulators, conductors or resistors.*
2. *Name two semiconductor materials.*
3. *How does doping a semiconductor affect its electron structure?*
4. *Explain what a P type material is.*
5. *How is a diode formed?*
6. *Explain how a diode acts as "a one way valve" to electron flow.*
7. *How does a diode affect the current flow in a simple AC circuit?*
8. *Explain how a diode would be forward biased.*
9. *What does the term "LED" stand for?*
10. *"The AC has been rectified to produce DC." Explain how rectification occurs.*

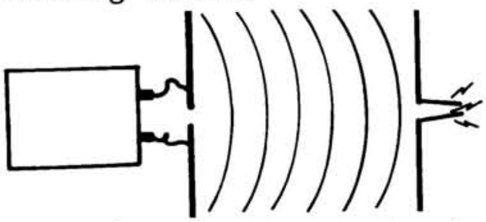
"I FINALLY GOT THIS MICROCIRCUIT READY FOR TESTING AND YOU SNEEZED!!!"

RADIO RECEIVERS

One of the most fascinating things about electronics is the way in which radio signals are sent from one place to another. To be able to speak into a microphone and have your voice reproduced in a receiving set some thousands of miles away is a truly remarkable phenomenon. This feat is made possible by radio waves.

THE FIRST RADIO TRANSMITTER

In 1888 Heinrich Hertz set up an experiment using a spark generator an aerial and a receiving aerial.



At the transmitter the generator charges the aerial about 50 million times per second	At the receiving aerial small sparks observed. Energy had travelled through space

Hertz showed that if electrons were made to accelerate rapidly then radio waves would be made. In the original experiment the electrons were accelerated some 50 000 000 times per second. This is known as the frequency of the transmitter. The radio waves have the same frequency. In honour of Hertz we use his name as the unit of frequency instead of "times per second". The abbreviation for Hertz is Hz.

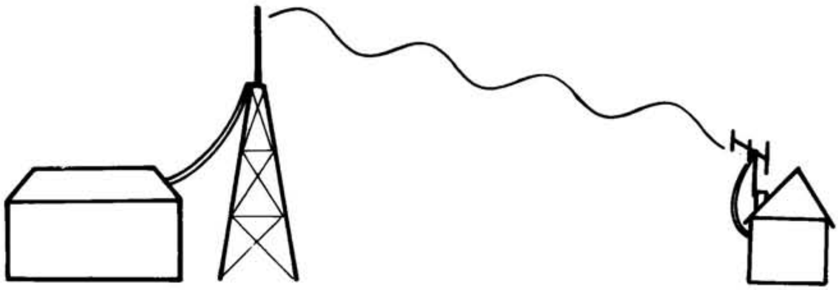
We now know that it is possible to generate radio waves of many different frequencies over a radio spectrum.

100 000 Hz	1 000 000 Hz	10 MHz	100 MHz	1 000 MHz
100 KHz	1 MHz		Very	Ultra
Low	Medium	High	High	High
Frequency	Frequency	Frequency	Frequency	Frequency

ONE MEGAHERTZ is higher frequency than ONE KILOHERTZ which is a higher frequency than one hertz

WHAT HAPPENS AT THE RECEIVING AERIAL ?

Notice that the transmitter produces high frequency alternating voltage. This causes high frequency AC to flow in the aerial.



Frequency of radio transmitter = Frequency of electricity in aerial = Frequency of radio waves = Frequency of electricity in aerial

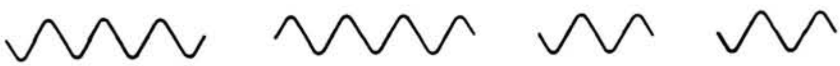
When the radio wave is absorbed by the aerial it produces a small alternating voltage. This may cause a small AC to flow which provides a signal for the TV or radio in the house.

The radio wave is usually called the carrier wave since it carries information to produce the sound for the radio and sound with picture for the TV.

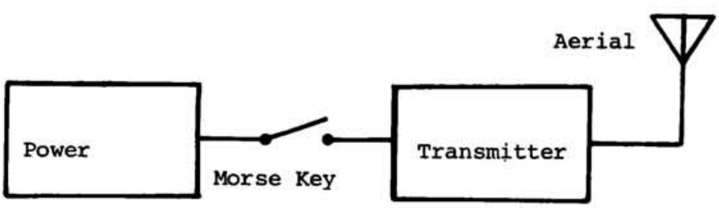
HOW RADIO WAVES CARRY MESSAGES

1. <u>Code</u>

One way is to simply turn the radio transmitter on and off to send a message by code. The Morse Code is usually used.



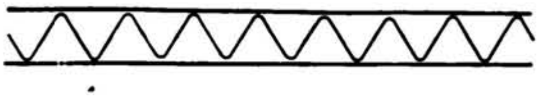
The diagram represents radio waves leaving the transmitter. They are properly called interrupted carrier waves.



A block diagram of an interrupted carrier wave transmitter

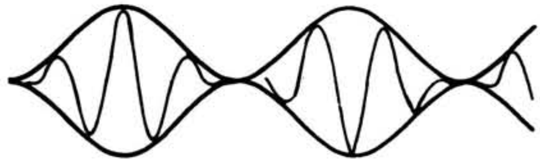
2. Modulation

Another way is to alter the radio wave so that it carries voice or speech information. One technique is to alter or modulate the size or amplitude of the radio wave so that it "carries" the speech information.



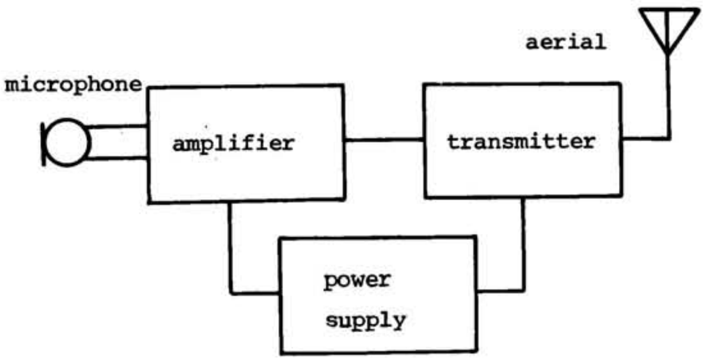
Carrier Wave

* Note same height or amplitude



Modulated Wave

* Note variation in wave height or amplitude



A block diagram of an AM Speech Transmitter

Notice in the transmitter that the sound is used to change or modulate the amplitude of the AC signal produced by the transmitter. We say the transmitter produces an amplitude modulated (AM) signal.

WHAT A RECEIVER DOES

The receiver has to recover the carrier wave of the transmitter and remove the modulation information (if any) and present it to us in a way we can understand.

Two important factors in receiver design are selectivity and sensitivity.

SELECTIVITY

This is defined as the ability of a receiver to separate a wanted signal from others close in frequency. A broadcast band receiver appears quite selective during the daylight hours. However in the late afternoon, when interstate signals are heard, a whistle is often heard, caused by an adjacent station being too near the one being listened to. No amount of tuning will solve this problem - the only solution is to increase the selectivity of the set.

<u>EXAMPLE</u>

```
                                                          |Band- |
          |Bandwidth|                                     |width |
    *     *     *     *                     *      *      |  *   |  *

   950   960   970   980   KHz             950    960    970    980   KHz

         Receiver A                              Receiver B

         WIDE BAND                               NARROW BAND
```

Receiver A is tuned to a centre frequency of 970KHz. Since the receiver has "poor" selectivity, stations on 960 and 980KHz will be heard if they are operating. We say the receiver has a wide bandwidth.

Receiver B is tuned to a centre frequency of 970KHz also, but because it has good selectivity, only that station would be heard. We say the receiver has a narrow bandwidth.

You may wonder why wideband receivers are made at all. The reason is that if a receiver has very good selectivity it tends to "chop" off some of the high frequency notes in the audio. Existing dials would also become difficult to tune.

Some receivers (particularly communication types) are fitted with variable selectivity, so that optimum bandwidth can be selected for prevailing conditions.

SENSITIVITY

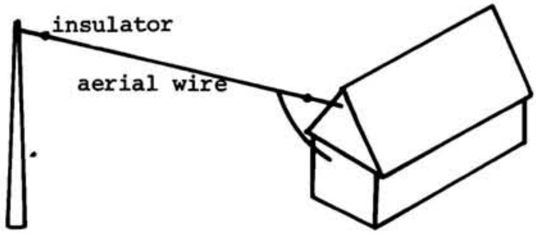
Sensitivity is the ability to separate signals from the surrounding noise. Where an insensitive receiver will receive only noise a sensitive receiver will find a signal at that point.

Insensitive receivers often bring in noise on local stations. Sensitive receivers may also bring in noise - but on stations that insensitive receivers cannot "hear".

THE SIMPLE DIODE RECEIVER

THE AERIAL

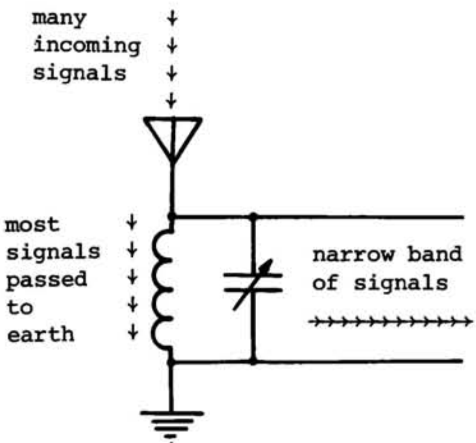
To receive and tune a radio signal the first step is to intercept the radio wave.



The aerial should be high, well clear of trees and power lines and should be insulated from the earth.

THE TUNED CIRCUIT

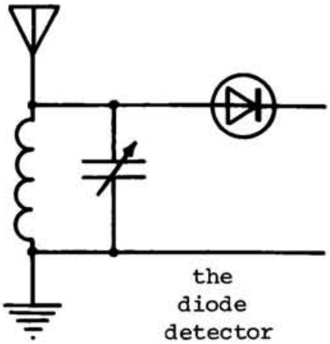
The aerial will intercept many different signals and they will produce many different frequency currents in the aerial. The receiver must select only one, or a narrow band of, the many signals from the aerial. The ability to do this is termed the selectivity of the receiver.



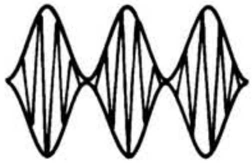
The parallel combination of the coil and the capacitor is called a tuned circuit. It passes all but one narrow band of frequencies to earth. Thus a narrow band is passed on to the next stage.

THE DETECTOR

Having selected the radio signal required, the audio must be separated from the carrier component. The audio must be detected or the signal demodulated. The diode helps in this process by rectifying the signal. This means only one half ("top or bottom") of the AC signal is passed to the next stage. This is because the diode will allow electricity to pass in only one direction.



the
diode
detector

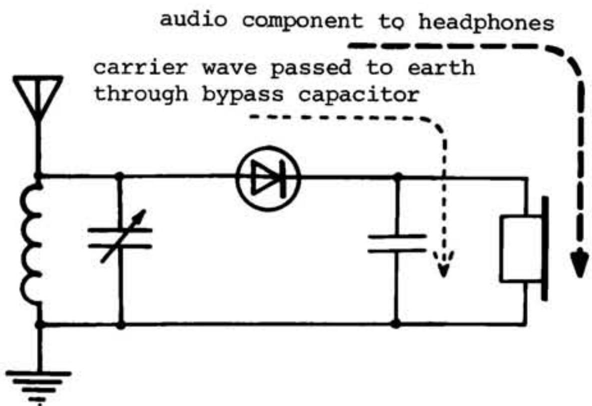


before detection

the signal
after detection

THE BYPASS CAPACITOR

Having detected the audio signal the carrier wave signal must now be bypassed. It is passed to earth by the bypass capacitor. This leaves the audio signal free to flow in the headphone circuit.



IMPROVING RECEIVER PERFORMANCE

The diode receiver has many shortcomings, especially in regard to sensitivity and selectivity.

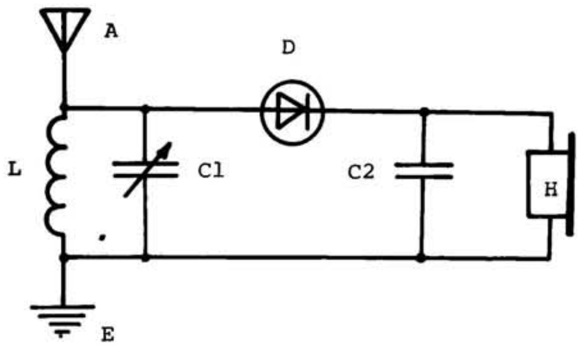
To improve sensitivity, it is a fairly easy step to add a transistor amplifier.

When this is done however, although the signals are stronger in the headphones, they will still be mixed together, as in the diode receiver.

To separate the signals, an additional winding, known as a "feed-back" or "regenerative" winding is added. This will increase selectivity, but under some circumstances the set will be difficult to adjust.

Present day receivers are of much more complex design.

THE DIODE RECEIVER



A - antenna or aerial
E - earth connection
L - aerial coil
C1 - variable capacitor 10-400 picoFarad
D - germanium diode OA91 or similar
C2 - capacitor 0.01 micro-Farad
H - headphone or crystal earpiece

OBTAINING PARTS FOR THE RECEIVER

It would be easy to simply buy new parts for this set. However it is very worthwhile to try and obtain some "good" secondhand parts from old discarded transistor radio sets.

SOME HINTS ABOUT THE PARTS

THE AERIAL COIL

Coil Diameter	Number of turns for wire gauge used 22 swg	24 swg	26 swg	28 swg	Taps
30 mm				110	at ¼, ½, and
38 mm			96	90	3/4 of the
45 mm		88	80	70	turns. For more
50 mm	82	72	68	60	adjustment tap
57 mm	71	64	60	52	every 10 turns.
65 mm	61	56	54	47	
70 mm	54	52			

The table allows you to know how many turns of wire to use for a given size of tube or former. Remember that old transformers from radio or TV sets can yield enough wire to wind many coils. However, the transformers must be pulled apart with care and patience. Remember the wire for the coil must be insulated.

The winding should go in one direction for the whole of the coil. Keep the turns laying side by side. Usually the wire is started and finished by securing it through holes in the former.

Ferrite rods often have windings present which are quite satisfactory. Try the coils by a trial and error method.

A good coil can be wound on a ferrite rod using about 60 turns of 26 swg wire with taps at the ¼,½ and 3/4 marks.

THE VARIABLE CAPACITOR

Tuning capacitors from old valve radios or transistor radios are useful for constructing the tuned circuit of the set. The air spaced multi gang capacitors from old valve radios are particularly useful. Only one gang of a multi gang capacitor should be used. Usually they are about 400 pF maximum capacitance per gang.

Make sure the moving plates do not touch the fixed plates.

Tuning capacitors from transistor radios often have the two sets of plates insulated from each other with plastic. They are often small in size, and in capacitance usually around 10 to 150 pF. This means that the coil they are to be used with should have more turns on it. It is well worthwhile to use the coil on the ferrite rod from the same radio as the capacitor came from.

THE DIODE

Germanium diodes such as the OA 91 type are usually used in diode receivers. They are more sensitive than the silicon diodes. Diodes can be tested with a continuity meter. They should conduct in one direction only.

HEADPHONES

High impedance phones work best. Older variety earphones often have their impedance marked on them. Values over 2 000 ohms are usually regarded as being high impedance. High impedance phones tend not to "load down" the diode receiver.

Earpieces as used in transistor radios may be used. The "crystal" variety have a very high impedance (and so work more successfully) than the "magnetic" type.

CONSTRUCTING THE BASIC DIODE RECEIVER

Remember that as you are constructing any project keep a record of the circuit that you used and a record of how the project worked and of any experiments that you may have tried.

When you have collected the components you need for the set, some thought must be given to the way you are going to assemble the receiver.

One good method is the "breadboard" approach where the parts are screwed to the base board and the circuit completed by soldering the leads of the components together, using nails as soldering points.

RADIO WAVES ARE GENERATED BY HIGH FREQUENCY ALTERNATING CURRENTS IN AERIALS

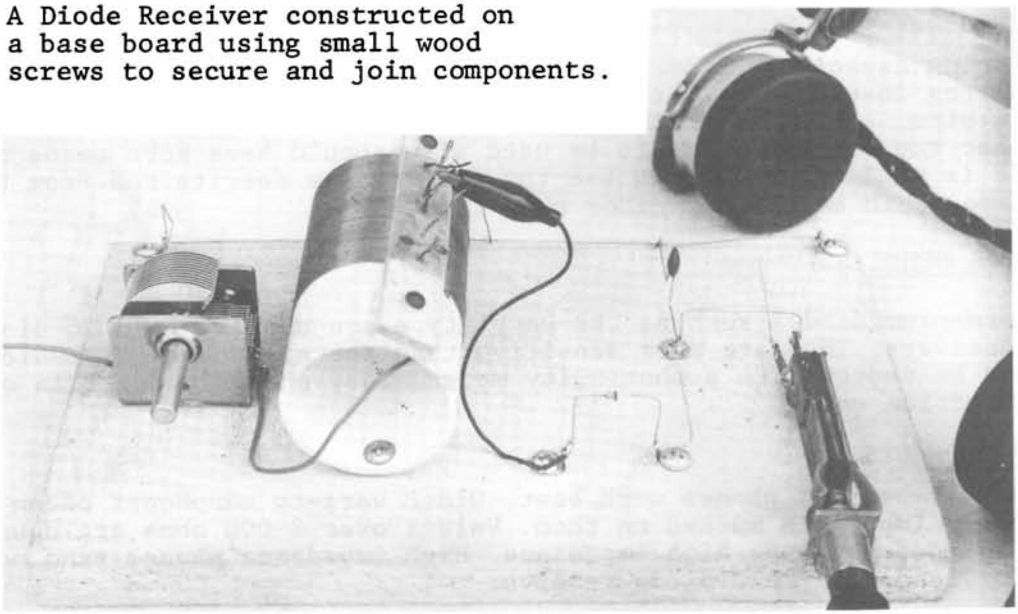
MODULATING THE CARRIER WAVES ALLOWS THEM TO CARRY INFORMATION

RADIO WAVES ABSORBED BY THE AERIAL FORM HIGH FREQUENCY AC

RECEIVERS SHOULD BE SENSITIVE AND SELECTIVE

RECEIVERS HAVE TUNED CIRCUITS AND DETECTORS

A Diode Receiver constructed on a base board using small wood screws to secure and join components.



REVISION QUESTIONS

1. *What band of frequencies are covered by the term "Very High Frequency"?*
2. *Why is a radio wave called a carrier wave?*
3. *What does modulation mean?*
4. *Describe the difference between a sensistive and a selective receiver.*

   Explain how these sections of a diode receiver help it to operate:

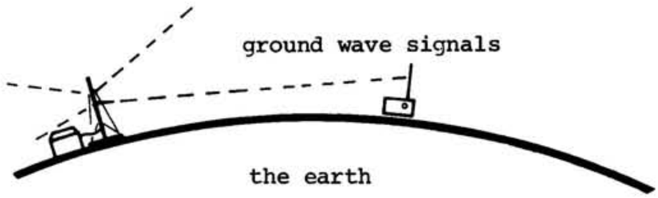
5. *aerial* 6. *tuned circuit* 7. *detector*
8. *bypass capacitor* 9. *headphone*
10. *Draw a circuit of a diode receiver and explain the function of each component.*

RADIO WAVE PROPAGATION

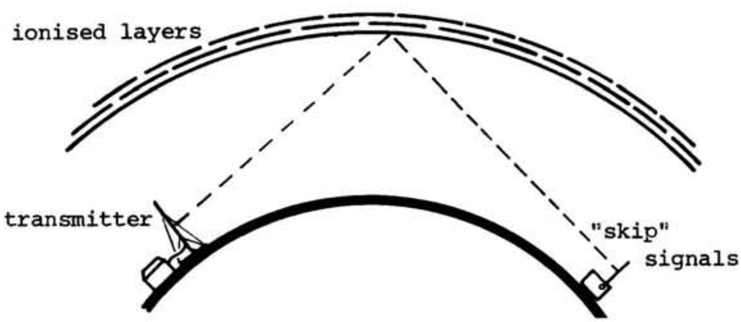
Propagation refers to the means by which radio waves travel through the atmosphere.

The paths signals take vary during the day and during the seasons.

If you live near a transmitter, such as one on the broadcast band (500 - 1600KHz) the signals you hear would come directly along the surface of the earth (ground waves).



Above the earth, layers of air become "ionized", that is, they become reflectors for radio waves. The frequencies which are reflected vary during the day and from season to season.



When the signals are reflected, they return hundreds of kilometres from the transmitter site to earth. Sometimes the signal bounces off the surface of the earth and is reflected again. The reflection process is often called "skip" or, in the latter case, "multiple skip" or "hop".

E A SIMPLE PROPAGATION EXPERIMENT

All you need for this experiment is a broadcast band radio.

1. During the middle of the day, select any two stations between 800KHz - 1600KHz.

2. Make sure there is at least 100KHz difference between the frequencies.

3. Make a note of the place on the dial where your two reference stations are located.

4. Tune between the two stations and make a note of any stations you can hear in the space. (Try to select a part of the band where there are no "in-between" stations).

5. Listen at 3.00 p.m. 4.00 p.m. 5.00 p.m. and 6.00 p.m. Record your results in a table like the one shown.

My Reference Stations are _______ and _______

Time	Number of Stations Heard
12.00 o'clock	
3.00 p.m.	
4.00 p.m.	
5.00 p.m.	
6.00 p.m.	

You will find that suddenly stations start to appear. These stations are those that are out of ground wave range during daylight hours. You will hear many stations outside your state.

If you care to tune between 500 - 700KHz you may hear New Zealand stations.

REVISION QUESTIONS

1. What does the word "propagation" mean about radio signals?

2. How does air affect radio waves when it becomes ionised?

3. Where in the atmosphere are the layers of air ionised?

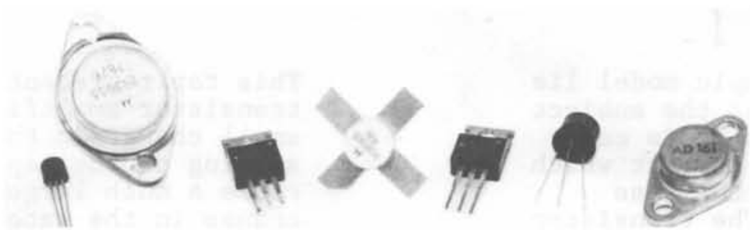
4. What are ground wave signals?

5. What are "skip" signals?

BIPOLAR TRANSISTORS

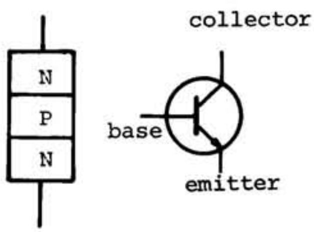
In 1947 at the Bell Telephone Laboratories the first working transistor was produced. The name "transistor" was coined from the words "transfer" and "resistor".

The picture shows many different types of transistors. They vary from large power transistors used in heavy duty power supplies to small signal amplifying transistors that operate at very high frequencies.



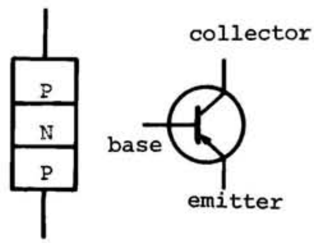
We will briefly consider how the bipolar type of transistor operates. Although the physical construction of various bipolar transistors differs, they all have three semiconductor layers based on N and P type materials. Three leads come from these layers - the emitter, base and the collector.

An NPN transistor



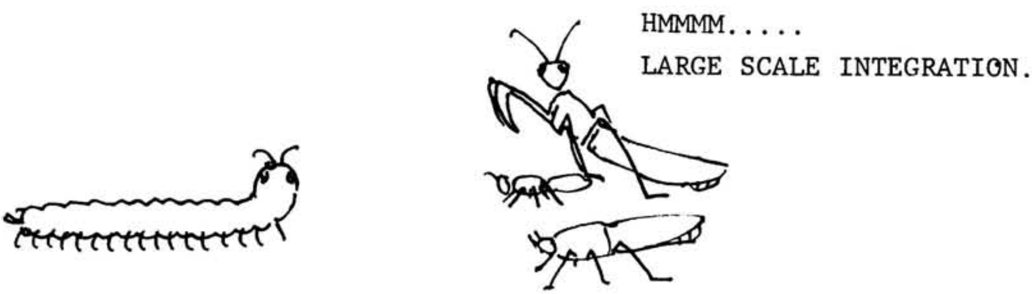
Structure Symbol

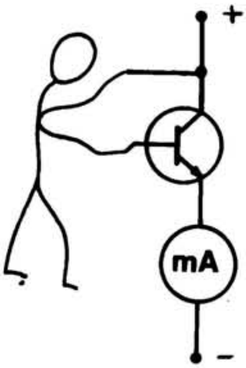
A PNP transistor



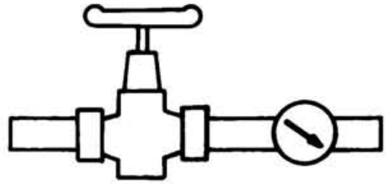
Structure Symbol

In essence the current flow through the three layers (emitter to collector) is controlled by the electrical condition of the base. Thus the transistor can act as an amplifier. A small electrical signal applied to the base can produce a larger amplified signal in the emitter - collector circuit.





In this simple model lie detector, as the subject sweats, his hands carry some extra current which flows into the base circuit. The transistor will allow a large current to flow in the emitter-collector circuit. This would cause the meter to indicate current flow.



This tap represents the transistor amplifier. A small change in the setting of the tap will cause a much larger change in the water current flowing into the tap. Thus the tap is acting as an amplifier.

BIPOLAR TRANSISTORS IN CIRCUITS

To operate bipolar transistors as simple amplifiers the transistors must be wired correctly in circuit.

An NPN transistor

collector more positive than emitter

Transistor will switch on when base is made more positive than emitter

A PNP transistor

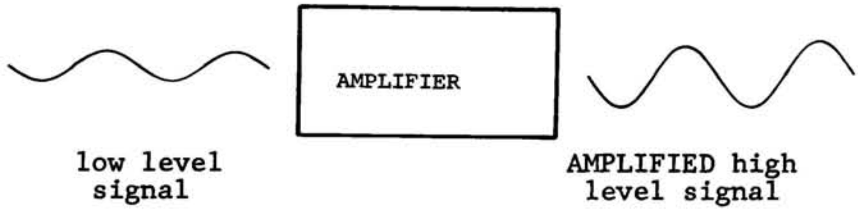
collector more negative than emitter

Transistor will switch on when base is made more negative than emitter

TRANSISTOR AMPLIFIERS

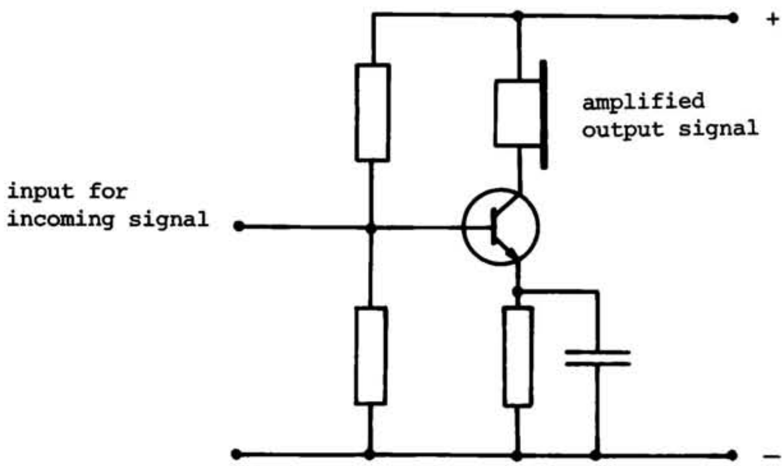
In the model lie detector, the transistor is acting as a sensitive switch - a small current applied in the base circuit causes a large emitter - collector current.

Transistors are frequently used as amplifiers where the incoming signal has to be faithfully reproduced without distortion.



This type of amplifier is called a linear amplifier

The diagram shows a typical common emitter amplifier



Some points to note

1. the circuit is called a common emitter circuit since the emitter forms part of the input and output circuits.

2. the base has two resistors which apply some constant base current to partly "turn on" the transistor. This base current is termed "base bias".

3. because the transistor is passing current, the incoming signal can act to turn the transistor further on or further off. Thus the output will be a faithfully amplified copy of the input signal.

TRANSISTORS HAVE SEMICONDUCTOR MATERIALS IN CONTACT

THE TRANSISTOR CAN ACT AS AN AMPLIFIER OF SMALL SIGNALS

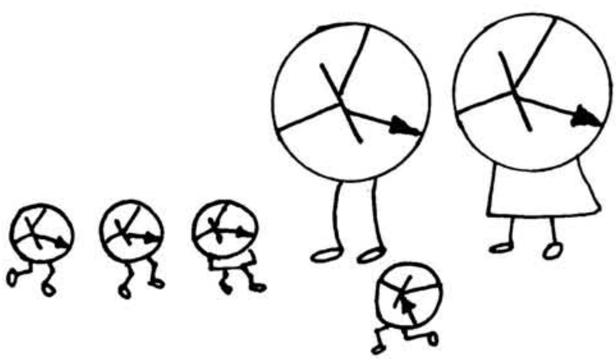
IN BIPOLAR TRANSISTORS THE CURRENT FLOW TO THE BASE CONTROLS THE EMITTER COLLECTOR CURRENT

THERE ARE NPN AND PNP BIPOLAR TRANSISTORS

FOR TRANSISTORS TO ACT AS LINEAR AMPLIFIERS THEY USUALLY NEED BIAS CURRENT

REVISION QUESTIONS

1. *How was the word "transistor" derived?*
2. *What is the symbol for an NPN transistor? On the symbol, label the emitter, collector and base.*
3. *What do the letters PNP tell you about a transistor?*
4. *When a transistor acts as an amplifier which part usually has the signal applied to it?*
5. *Explain what a signal amplifier is.*
6. *How is a transistor wired in a common emitter amplifier?*
7. *"The transistor is turned on". What does this mean about the transistor?*
8. *What electrical condition will ensure that an NPN transistor turns "on"?*
9. *What is meant by the term "linear amplifier"?*
10. *How is a transistor in a common emitter amplifier supplied with base bias current?*



ONE OF THE NEIGHBOURS' I THINK.

TEST EQUIPMENT

When faults develop in electronic equipment, special instruments are available to help us find the circuits that are not operating properly.

To have fault finding equipment is quite handy. However, it is the skill in using the equipment correctly to speedily find the fault that is really important.

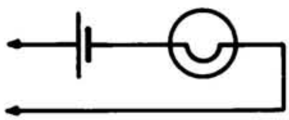
OBVIOUS FAULTS

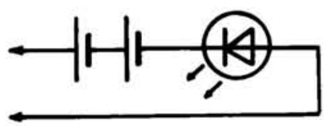
When a circuit fails to work, before reaching for the test equipment use your eyes. Look for obvious faults such as broken wires, poorly soldered joints, loose connections or flat and leaky batteries.

THE CONTINUITY TESTER

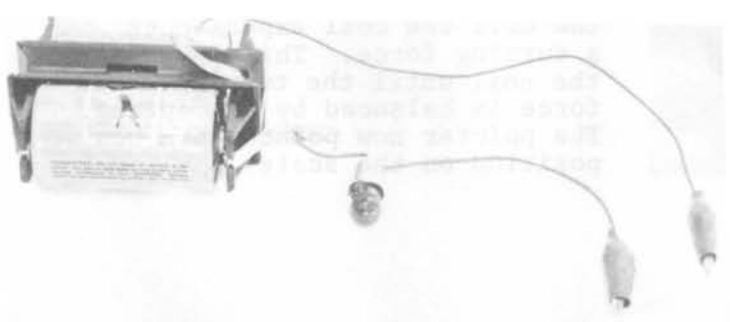
Many faults in equipment and projects occur simply because an electric circuit has a break in it. A wire may be loose or poorly soldered. Sometimes wires break inside their plastic coating. The circuit is no longer continuous.

There are many variations in constructing continuity testers, but they all indicate when a circuit is complete by checking to see if current will flow. A continuous circuit will allow current to flow causing the bulb or LED to light.





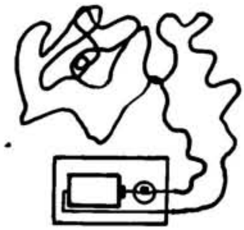
Construction of a continuity tester is simple. A torch could be modified by breaking the circuit and then connecting two alligator clips with leads.



This simple continuity tester uses two 1½ volt cells in series (in the cell pack) and a 3 volt bulb.

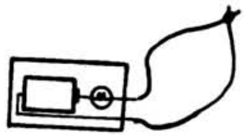
TESTING WITH A CONTINUITY TESTER

Testing a length of wire.



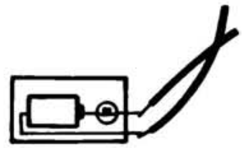
The lamp should light on the tester telling that current can flow through the wire. The wire circuit is continuous.

Testing a soldered joint.



The lamp should light on the tester telling that current can flow through the soldered joint. The solder circuit is continuous.

Testing insulation on wires.

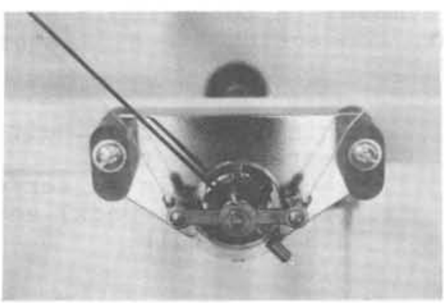


The lamp should not light on the tester telling that current cannot flow from one wire to the other. The circuit is not continuous and the plastic insulation is good.

THE MOVING COIL METER

The continuity tester using a lamp or a LED simply tells you if a circuit is continuous or not. It cannot indicate inbetween conditions (such as medium or high resistance) very well.

A meter has a scale and not only indicates current flow but tells you how much.

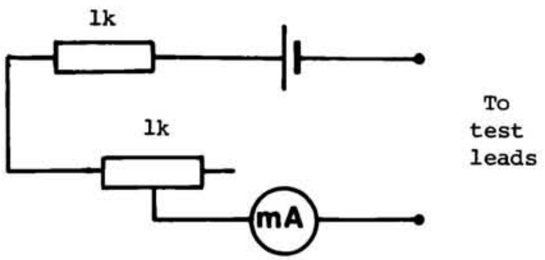


Notice the meter pointer is attached to a wire coil in a magnetic field. The coil has a very fine spiral spring attached to it.
When current flows through the coil the coil experiences a turning force. This moves the coil until the turning force is balanced by the spring. The pointer now points to a new position on the scale.

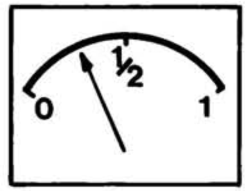
With strong magnets and a light fine wire coil a very sensitive current meter is formed. Current meters are usually specified by their fsd value and the resistance of the moving wire coil.

<u>EXAMPLE</u> 1mA fsd - 100Ω meter means a meter with a resistance of 100Ω which will read full scale with a current of 1mA.

USING A METER AS A CONTINUITY TESTER



Meter 0-1 milliamp 100 ohms



Meter face

sample readings

0 = circuit not conducting
½ = circuit acting as a resistance
1 = circuit very conductive

Notice that the tester really measures current flow around the circuit being tested. The 1K potentiometer is used, with the test leads touching, to set the current to exactly 1mA so the meter reads full scale.

USING A METER TO READ VOLTAGE OR CURRENT

The most common meter generally available is the 0-1 milliamp meter. This meter is limited to measuring DC currents in the range 0 to 1 milliamp DC.

Unfortunately, there are many measurements that could be made, such as voltage or higher currents, that could not be made with such a meter.

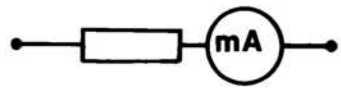
" BILL SAID HE'D BE CHECKING FOR. DRY JOINTS TONIGHT."

Fortunately, by adding resistors, it is possible to change the ranges the meter will measure. The value of the resistor depends on the "range" over which you wish the meter to operate (e.g. 0-100 volts) and the internal resistance of the meter, which should be stated somewhere on the meter. Ranges from 75-100 ohms are typical for a 0-1mA meter.

CURRENT MEASUREMENT

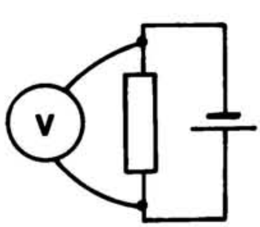
SHUNT VALUE	RANGE
11 ohms	0-10 mA
1 ohm	0-100 mA
0.1 ohm	0-1 amp

VOLTAGE MEASUREMENT

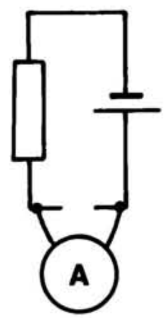


MULTIPLIER VALUE	RANGE
900 Ω	0-1v
9 900 Ω	0-10v
99 900 Ω	0-100v

Notice the way meters should be wired for different measurements.



When measuring VOLTAGE the meter is placed in parallel with the circuit under test



When measuring CURRENT the meter is placed in series in the circuit

USES FOR FIXED RANGE METERS

1. To measure battery voltage/current
2. In fixed equipment operating within the range of the meter
3. In battery chargers
4. Signal strength meters in receivers, etc.

MULTIMETERS

Multimeters consist of a single meter attached to a rotary switch or other device which allows various multipliers and shunts to be placed in circuit with the meter to read volts, current and resistance. AC and DC ranges may be provided along with provision for measuring capacitance and power, etc.

Some cheaper multimeters are available at less cost than a single fixed meter.

Multimeter Ranges

DC volts

2.5,10,50,250,500 and 5 000 volts.

AC volts

10,50,250,500 and 1 000 volts.

Resistance

0 to 10 000 000 ohms in 4 ranges.

DC Current

50μA,5mA,50mA and 500mA.

USING A MULTIMETER

1. Become familiar with the scales.

2. To measure resistance, select the required range join the probes and use the "OHMS ADJUST" knob to make the pointer indicate zero. You are now ready to measure resistance accurately. NOTE : Each time you change to a different resistance range you will have to recalibrate the meter.

3. Leave the meter set to the highest AC in range in storage. In this position the meter is less easily damaged.

4. Always select the correct range before connecting the meter leads. If you are unsure, start with the highest range.

5. On DC ranges, observe correct polarity - the positive lead of the meter must go to the positive part of the circuit.

ACCURACY

Meter accuracy depends largely on the "trueness" of the shunt and multiplier resistors. Some of the cheaper multimeters have a habit of "loading" the circuits they are testing. By drawing considerable current from the circuit under test, they may change operating voltages and give false readings. The "loading" factor is expressed in ohms per volt, for example

10kw/volt or 10 000 ohms per volt

The higher the quoted resistance value, the "truer" the reading will be.

OTHER METERS

The Vacuum Tube Voltmeter and Field Effect Transistor Meter are more accurate than most conventional meters, and more expensive.

Digital Meters, which show numbers in their display directly, are fast replacing the conventional style of meter.

LED Digital Multimeter

LCD Display Multimeter.

Note that the meter is set to measure the resistance of the resistor connected to the meter.

CONTINUITY TESTERS CHECK FOR LOW RESISTANCE CIRCUITS.

MOVING COIL METERS MEASURE CURRENT.

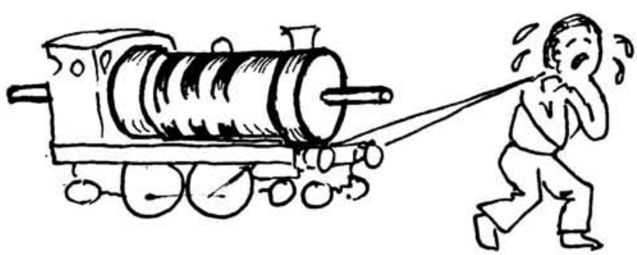
CURRENT METERS CAN BE EXTENDED TO OTHER CURRENT RANGES USING SHUNT RESISTORS.

CURRENT METERS CAN BE USED TO MEASURE VOLTAGE IF USED WITH SERIES RESISTORS

VOLTAGE, CURRENT AND RESISTANCE CAN BE MEASURED WITH A MULTIMETER.

REVISION QUESTIONS

1. *What does a continuity tester do?*
2. *Draw the circuit of a continuity tester.*
3. *List four parts of a moving coil meter.*
4. *What does the description "10 mA fsd 50 ohm" mean about a meter?*
5. *Show how a continuity tester can be built using a meter.*
6. *How does a potentiometer aid the operation of a meter continuity tester?*
7. *Show on a diagram how an ammeter and a voltmeter should be wired to measure voltage across and current through a bulb in a torch.*
8. *What is the difference between shunt and multiplier (series) resistors in meters?*
9. *In a current meter why must the shunt resistor have a very low value for a large current range on the meter?*
10. *Explain how you would set up a multimeter to measure the resistance of a resistor in a radio.*



WELL YOU SAID THAT AMMETER NEEDED A SHUNT RESISTOR.